GEOGRAPHICAL BULLETIN

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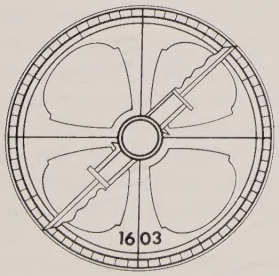
GEOGRAPHICAL BULLETIN

Champlain's astrolabe, lost near the Ottawa River in 1613 and found in August 1867, has been adopted as the symbol of the Geographical Branch. Appointed Geographer to the King of France in 1603, Samuel de Champlain is thus recognized as the forefather of Canadian geography.

The statue of Champlain stands on Nepean Point, Ottawa. The sculptor has used a degree of artistic license in that the astrolabe is held upside down.



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AREA-DIFFERENTIAL PRODUCTIVITY OF AGRICULTURAL RESOURCES AND OFF-FARM MIGRATION ON THE CANADIAN PRAIRIES

Michael L. Szabo

ABSTRACT

Differentials of productivity of the resources used in crop and livestock production in the major soil zones were analyzed in terms of their marginal returns and found to be relatively highest in those areas of the Brown soil zone which have the most stable farm population. In all soil zones, the livestock sector showed generally more favourable resource returns than did the crop sector. Capital productivity in both sectors was more favourable than that of the other resources. Low productivity of labour prevailed in both sectors and in every soil zone, and was lowest in the areas with the least stable farm population. Using statistical models devised by the author in a previous paper, areas of farm population imbalance were identified on the basis of overpredicted farm incomes and underpredicted outmigration.

RÉSUMÉ

L'auteur a analysé les différentielles de la productivité distinctive des ressources utilisées dans la production des récoltes de grain et du bétail en fonction de leur rendement marginal dans les principales zones pédologiques des Prairies. Les différentielles se sont montrées relativement plus élevées dans les régions appartenant à la zone des sols bruns et possédant une population agricole plus stable. Dans toutes les zones pédologiques en général, le secteur bétail démontre une meilleure utilisation des ressources que le secteur culture. Dans ces deux secteurs, la productivité des immobilisations était supérieure à celle provenant d'autres ressources. De plus, ces deux secteurs affichent parfois un faible rendement pour le travail investi, condition qui se retrouve dans chaque zone pédologique et qui touche son niveau le plus bas dans les régions où la population agricole est la moins stable. Grâce à des modèles statistiques établis dans un ouvrage antérieur, l'auteur signale les régions de population agricole en déséquilibre, lesquelles s'isolent sur des bases de revenus agricoles surestimés et de dépeuplement sousetimé.

INTRODUCTION

In a previous study (Szabo, 1965) depopulation of farms was examined in light of economic conditions of agriculture as described by a number of economic indicators. Although this revealed interesting relationships, the differences in productivity of resources in areas with known migration histories remained unexplored.

A number of variables used in that study, all relevant to the size of farm operation in physical terms, could not be examined or properly related to the migration pattern. Another variable, *return on capital,* was not investigated because important features of this indicator could not be observed and related to population movement. Also, *labour supply,* or eventual oversupply, as a possible contributor to outmigration could not be fully investigated.

The purpose of the present study is to examine by area the income-generating capabilities of the agricultural resources of the Prairie Provinces in light of their previously investigated migration experience.

Within the limitations of the data and methods, an attempt will be made to obtain further insight into the interplay between de-

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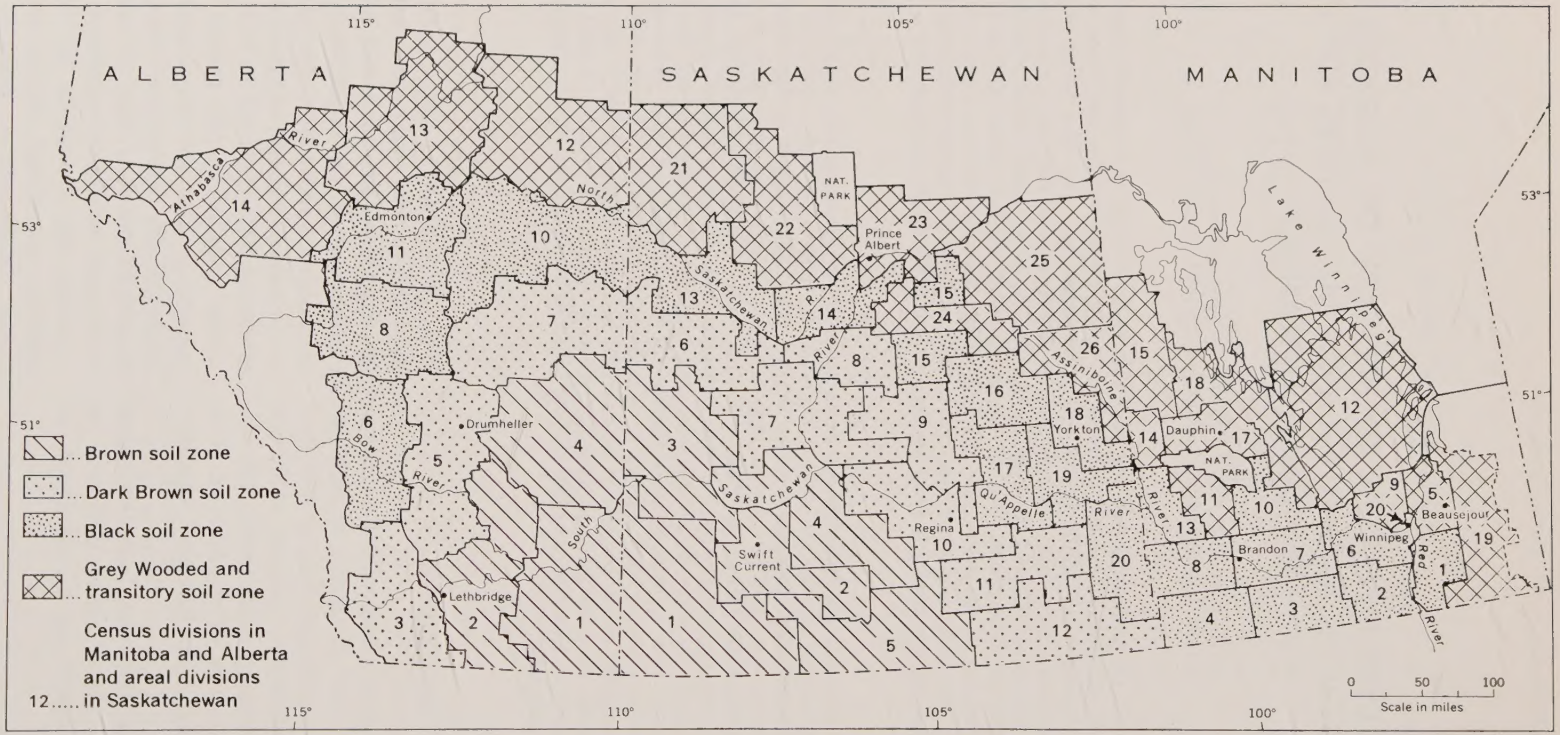

FIGURE 1. Soil zones and areal divisions in the southern section of the Prairie Provinces.

mographic processes and economic conditions by searching for reasonably definite answers to such questions as:

(1) is outmigration from farms coincident with low productivity of land, capital or labour, or some combination of the three?
(2) to what extent would unit measures of additional resource inputs raise the amount of gross incomes where outmigration was high in recent years?
(3) how seriously does hidden underemployment affect labour productivity and thus contribute to migration from the farms in heavily depopulating areas?

METHODOLOGY

Areal system of analysis

The area under investigation in this study is the southern, settled parts of the Prairie Provinces where agriculture is a major industry. National and provincial parks, Indian reserves and certain fringe areas such as the Peace River district are excluded (Figure 1).

The system of areal units of observation used in this study is similar to that of the former paper except that the number of areal units was increased within each major soil zone to facilitate the computation of productivity measures. The system of areal units obtained for the purpose of this study also satisfies the requirements specified previously (Szabo, 1965, p. 189):

(1) each areal division belonged to only one major soil zone and was, as far as possible, homogeneous;
(2) within each areal division farm population density was fairly uniform;
(3) as far as possible areas were comparable in size.

Data used in tabulating aggregates for each area of observation were obtained at the census subdivision level through the courtesy of the Dominion Bureau of Statistics.

Production functions of the Cobb-Douglas type (Griliches, 1963, p. 421) were computed from cross-sectional data obtained from the 1961 census statistics on agriculture. Since agriculture is a fairly homogeneous industry which was further stratified by type such as crop and livestock production and by major soil zones, it was deemed appropriate, as well as commensurate with available resources, to use the Cobb-Douglas type of production function.

The equation can be written in the form

$$\log Y = \alpha + a_1 \log x_1 \ . \ . \ . \ a_k \log x_k$$

where Y is the product of the industry, α is the regression constant and $x_1 \ . \ . \ . \ x_k$ are various inputs used in the production. Productivity of resources was measured in terms of marginal productivity.

Allowance was made for differences in the mix of output and a separate set of equations was derived for crop and livestock production respectively. As in the previous study, the three major soil zones considered are (1) Brown and Dark Brown soil zone, (2) Black soil zone and (3) Grey Wooded and Transitory soil zone. Since within each of these zones agricultural conditions, resources and farming practices, on one hand, and depopulation, on the other, show a certain measure of homogeneity, these zones have been accepted as a frame of reference. Accordingly, in order to observe regional differences, an equation for crop production and another for livestock production were computed for each major soil zone.

Specification of variables

The data include all farms recorded in the census and are presented in the form of arithmetic averages per farm.

As a measure of *output,* the values of (1) crops sold and of (2) livestock, poultry and dairy products sold, were calculated separately because they were listed separately in the 1961 census. Although these data differ from the farm cash income figures published by the Agriculture Division of the Dominion Bureau of Statistics they were nevertheless considered suitable for such areal study. In this analysis the emphasis is on establishing quantitative information on the relative productivity performance of areas rather than on computing accurate productivity measures reflecting actual production conditions at the individual farm level. Data on the value of products used in farm households were neither compiled nor added to the output.

Land input was measured in physical terms, acres of cropland per farm being the measure

used in the crop production functions. No allowance was made for differences in the quality of cropland since there was no suitable practical method available for estimating this. No variable on pasture land inputs was constructed for the livestock production functions because of the difficulties arising from such factors as (1) differences in the quality of the improved and unimproved pasture land, even within relatively small areas, and (2) lack of information regarding the land actually used as pasture whether classified as such or not. Perhaps with further experimentation it would be possible to establish a meaningful single measure of pasture land input for larger areas, but the resources needed for this work were not available at the time of the present study. It is realized, of course, that the omission of such a variable is an important source of bias in the productivity estimates (Griliches, 1957, pp. 9-14).

Capital inputs were estimated from census data on various stocks of capital by converting them into capital flow data in the following manner: depreciation and interest were computed as straight proportions of the capital stock, operating and maintenance estimates were added to these proportions. Two major components of capital inputs were constructed: (1) machinery services, and (2) livestock services:

Machinery services: The value of farm machinery and equipment was multiplied by 0.15 to convert it into flow data.* To this amount the prorated share of the total provincial expenditures on machinery operating and maintenance services as shown in the DBS Farm Net Income, 1961, was added for each area of observation.

Livestock services: The combined value of livestock and poultry was multiplied by 0.08 to obtain flow data.** The prorated share of the total provincial expenditures on feed as indicated in DBS Farm Net Income, 1961 was then added to this figure for each area of observation.

Labour input: Since the census does not provide direct information on the total amounts of labour actually used in the agricultural enterprise the concept of available labour had to be applied in constructing the variable on labour input. No allowance was made for differences in quality of labour, the variable being computed in physical terms i.e., labour-weeks per farm.

Labour input estimates had three components: (1) *own labour,* (2) *paid labour* and (3) *unpaid family labour. Own labour* was calculated as 300 days per year per operator, minus off-farm work. For operators of the age of 65 and over, labour inputs were entered with an arbitrary weight of 0.6, thus accounting to some extent for differences in labour intensity. In the *paid labour* component only male labour was included. The *unpaid family labour* was considered less intensive than either the *own labour* of the operator or that of the hired help. For this reason, the *unpaid male labour* was assigned an arbitrarily estimated weight of 0.66 and the *female labour* a weight of 0.40.

Data on capital services and/or labour obtained by the above process were aggregates which had to be divided between crop production on the one hand and livestock production on the other. This was done by utilizing census data on the type of farming. The size of cropland also was applied as a correcting factor in arriving at estimates on labour available for crop production. It is realized, of course, that this procedure at best is only an acceptable approximation and necessarily leaves some impurity in the estimates.

As a result of this computation the following variables were obtained for each area of observation:

Crop production

$X^{(C)}$ = dollar value of crop production
$X_1^{(C)}$ = acres of cropland
$X_2^{(C)}$ = dollar value of capital services
$X_3^{(C)}$ = number of weeks of total labour

Livestock production

$Y^{(L)}$ = dollar value of livestock production
$Y_1^{(L)}$ = dollar value of capital services (combined value of livestock and machinery services)
$Y_2^{(L)}$ = number of weeks of total labour

Certain items of expenditures such as interest on indebtedness, electric power and fertilizer

*It was arbitrarily estimated that about 15 per cent of the value of machinery and equipment can be written off as annual depreciation.

**The annual depreciation of the livestock was taken at an arbitrary 8 per cent of its value.

Table 1

Characteristics of farms by major soil zones (average per farm), Prairie Provinces, 1961

Variable	Unit	Total area		Soil zones: Brown and Dark Brown		Black		Grey Wooded	
		Means	Std. dev.	Means	Std. dev.	Means	Std. dev.	Means	Std. dev.
Crop function									
Cropland	acre	223	80	318	40	202	37	149	34
Capital services	$	1,598	646	2,283	410	1,421	428	1,080	469
Labour	week	40.6	9.8	46.6	5.2	38.0	10.9	35.6	9.9
Output	$	2,954	1,562	4,667	1,262	2,529	859	1,595	727
Livestock function									
Capital services	$	1,225	596	1,234	723	1,362	624	1,073	384
Labour	week	24.0	9.9	18.6	8.2	27.6	11.2	25.9	7.9
Output	$	2,151	1,470	2,370	1,713	2,508	1,557	1,450	481

were omitted because of the difficulties involved in computing their areal distribution. The management factor as a form of input was also omitted, since no reliable basis for its specification was available. Also, it was not possible from the census data to specify separately the various forms of capital used in different sectors as applied in Hjelm and Sandgrist (1964, pp. 355-356).

The degree of aggregation applied here achieves a certain measure of substitutability between inputs insofar as possibility of choice exists between them in the production process. To the extent that they complement each other in actual situations, however, the problem of inter-correlation between inputs exists and consequently the estimates are subject to larger sampling error.

A number of production functions were derived on the IBM 705 computer of the Dominion Bureau of Statistics, using a stepwise regression program. The program has been developed by J. J. Foster formerly of the Scientific Section, Central Programming Staff, Dominion Bureau of Statistics from earlier work by K. W. Smillie. Productivity estimates, based on the equations most acceptable for analytical purposes are discussed. In the first part of the following discussion the results of the productivity analysis will be presented; in the second the productivity performance of areas will be compared with the actual and predicted regional migration pattern.

PRODUCTIVITY ANALYSIS

Marginal analysis of resources

Basic statistics characterizing farms in the major soil zones, are given for reference purposes in Table 1. Mean levels of resources and returns, together with their standard deviations, are shown by primary (crop) and secondary (livestock) production.

Regression coefficients and related statistics for crop production functions are presented in Table 2 and for livestock production functions in Table 3. All equations are accepted for analysis at the 1 per cent level of probability on

Table 2

Regression coefficients and related statistics (crop function), Prairie Provinces, 1961

Item	Soil zones: Brown and Dark Brown	Black	Grey Wooded
Value of α; log form	−0.0112	−0.4882	0.0145
Value of β (elasticities)			
Cropland	0.0835†	0.5980*	0.2469*
Capital services	0.9968*	0.7268*	0.8511*
Labour	0.3099*	0.1369†	0.0424**
Sum of elasticities	1.3902	1.4617	1.1404
Standard error:			
Cropland	0.0953	0.1163	0.0931
Capital services	0.0865	0.1400	0.1033
Labour	0.1248	0.1103	0.1540
Coefficient of multiple determination (R^2)*	0.9153	0.9353	0.9728

*Significant at .01 probability level

†Significant at .20 probability level

**Nonsignificant at .25 probability level or greater

Table 3

Regression coefficients and related statistics (livestock function), Prairie Provinces, 1961

Item	Soil zones		
	Brown and Dark Brown	Black	Grey Wooded
Value of α; log form	0.1399	0.1760	0.0156
Value of β (elasticities)			
Capital services	0.9475*	0.9152*	0.8772*
Labour	0.2246†	0.2353†	0.2405*
Sum of elasticities	1.1721	1.1505	1.1176
Standard error:			
Capital services	0.1025	0.1267	0.0411
Labour	0.1356	0.1480	0.0852
Coefficient of multiple determination (R^2)*	0.9251	0.8930	0.9727

*Significant at .01 probability level

†Significant at .10 probability level

the basis of the F tests although, as the t ratios show, not all of the elasticity coefficients are significant statistically at the same level. In fact, some of them, such as cropland in the Brown soil zone and labour used in crop production in the Black soil zone, are significant only at the 20 per cent level. Labour used in crop production in the Grey Wooded soil zone is not significant even at the 25 per cent level or higher.

For both crop and livestock, each of the elasticities, i.e., logarithmic regression coefficients, is positive and less than 1.0, suggesting that the output would increase with an increase of input, but at a diminishing rate. This means that as more of the resource is used, the return per unit of the resource will decline (Tintner, 1944, p. 29). In the Brown soil zone for example, with every other input held constant, a 1.0 per cent increase per farm in the size of the average cropland actually in cultivation would result in an increase of only 0.0835 per cent in the value of crop production. In the Black soil zone, on the other hand, a 1.0 per cent increase of the cropland under the same conditions would increase the return from crop production by 0.5980 per cent at the average farm level.

When the sums of elasticity coefficients are not significantly different from 1.0, as is possible for all the livestock functions and for the crop function in the Grey Wooded soil zone, constant returns to scale are indicated. (The appropriate tests could not be made as the covariance terms of the regression coefficients were not given in the computer print-outs.) Should a proper test show, for example, that in the Brown and Black soil zones the sums of elasticities of crop production are significantly over 1.0, this would suggest that resources in the present combination could be used with increasing efficiency if the scale of operation is enlarged.

Productivity estimates shown in Tables 2 and 3 were derived from these equations in terms of marginal productivity. This, in turn, is derived from the elasticity coefficient of the mean resource in operation, the mean product and the mean resource quantity (Heady and Shaw, 1954). These estimates are valid only if the quantity of all other resources are held constant at the average farm level. Values of gross mean products are presented in Table 4. A given amount of marginal product refers to the increase in output which would result from increasing the average level of an input by a unit measure of it. For example, "one more dollar" spent by the average farm on capital services in crop production in the Grey Wooded soil zone would add $1.16 to the average value of products, provided other resources are used in average quantity. In other words, one additional dollar expenditure on crop capital services would return itself and yield an additional 16 cents.

Resource productivity in crop production

Values of marginal products of resources are given in Table 5.

The *marginal productivity of cropland* in the Brown soil zone is $1.22 per acre which means that if the average size of cropland in this soil zone is increased by one acre from 318 acres to 319 acres, and if capital services and labour inputs remain at their respective means of $2,283 and 46.6 weeks per farm (Table 1) the output would increase by $1.22. The values in Table 5 assume the relative magnitudes which would be expected in these areas on the basis of the natural conditions of soil type and climate required for agriculture. There are, however, important economic implications in the marginal productivity of land when it becomes a matter of making decisions both at the level of regional policy and of individual enterprise.

Table 4

Average actual output and gross mean product of resources per farm, Prairie Provinces, 1961

Variable	Unit	Soil zones		
		Brown and Dark Brown	Black	Grey Wooded
Crop production				
Average actual output	$	4,667	2,529	1,595
Mean product				
Cropland	$ per acre	14.67	12.52	10.70
Capital services	$ per $	2.04	1.78	1.48
Labour	$ per week	100.02	66.55	44.80
Livestock production				
Average actual output	$	2,370	2,508	1,450
Mean product				
Capital services	$ per $	1.92	1.84	1.35
Labour	$ per week	127.41	90.87	55.98

In a regional economy such as that of the Canadian prairies, where not all the available land is utilized each year and where, as a result, some room is left for manoeuvre, the total area of land under crops can be influenced by internal or external market conditions. Should an increase in cropland become desirable in response to favourable market situations, such an increase is more advantageously undertaken in areas where the marginal productivity of cropland is relatively high, for example, in the Black soil zone. Should the contrary situation arise, where the withdrawal of land from crops is advisable in order to avoid further decreases in prices, for example, this withdrawal should be made first in areas such as the Brown soil zone where the marginal productivity of land is relatively low. Withdrawal of such land will result in a relatively small decrease in output and a saving of input.

When the problem of enlarging or reducing the area of land under crops presents itself at the individual farm level, the decision is profoundly affected by marginal productivity values. A farmer who owns sufficient cropland and to whom the enlarging of operations seems advisable, may not benefit by putting more land under crop if the marginal product of land in question is lower than the rental rates of land. If he does not own more land than he already cultivates and can only increase his land input by renting, he may be quite unwilling or unable to do so if rental rates are higher than the marginal productivity — provided he is aware of this factor. The problems of marginal productivity in relation to resource prices are discussed in more detail in the section entitled "Productivity and resource prices."

The *marginal productivity of capital services* for each dollar spent in capital services in crop production is shown in Table 5 to be greatest in the Brown soil zone. Not surprisingly it is

Table 5

Marginal returns on resources per farm, Prairie Provinces, 1961

Resource	Unit	Soil zones		
		Brown and Dark Brown	Black	Grey Wooded
Crop function				
Cropland	$ per acre	1.22	7.49	2.64
Capital services	$ per $	2.03	1.29	1.16
Labour	$ per week	31.00	9.11	1.90
Livestock function				
Capital services	$ per $	1.82	1.68	1.18
Labour	$ per week	28.62	21.38	13.46

highest where the size of crop production is largest in terms of all the variables. On the other hand, it is also noteworthy that in the Grey Wooded soil zone where operations are the smallest and where relative overmechanization is suspected (W. Darcovich, 1958, p. 89) the marginal productivity of capital is still above 1.0. In the Black soil zone this value seems to have a comfortable edge over 1.0, so that further capital spending would return both itself and the cost of capital without further enlarging the area of cropland and/or the labour input. It would be quite a different situation if there were room for capital spending for technological improvement, but it should be remembered that some of the latest-model or new types of farm machinery may not increase the output at all.

As shown in Table 5, the marginal productivity of labour in crop production differs widely in the three soil zones. The smaller farms and the smaller amounts of capital per work week used on the farms in the Black and Grey Wooded soil zones deflate the labour productivity of these zones relative to the Brown soil zone, the capital-labour ratio varying in the same direction as labour productivity. Labour productivity would be higher, of course, if less of it were used. The extremely low figures for the Black and Grey Wooded soil zones could also be attributed to two factors: (1) the concept of *available labour* applied in constructing the *own labour* component of the labour variable as against the *actually used labour;* and (2) the fact that all *census farms* are included in this study and that the proportion of the small-scale farms in the fringe areas of the Black and Grey Wooded soil zones is quite heavy. For these and all other farms, an arbitrary 300 days/year was taken as the amount of available labour of the operator. Obviously a small-scale operator may not use the total amount of this time since it may not be required; as a result, his labour is underemployed. Labour productivity values in Table 6 express to some extent this relative *underemployment of labour* in crop production.

Resource productivity in livestock production

Marginal returns on both capital and labour are highest in the Brown and smallest in the Grey Wooded soil zones, while the Black soil zone occupies a median position (Table 5). Returns are higher for livestock production than for crop production in both the Black and Grey Wooded soil zones but somewhat smaller in the Brown soil zone. The broad implication of this situation is that for any intra-regional addition or re-allocation of resources at the average farm level, there will be greater returns in the Black and Grey Wooded soil zones if such resources are applied to livestock production rather than to crop production. The opposite holds true in the Brown soil zone.

In the Brown soil zone, the marginal return for each dollar spent on livestock capital is $1.82, slightly less than the returns on crop capital ($2.03), although in both sectors the marginal returns were higher than in the other soil zones. In the Black soil zone capital productivity for each dollar spent is larger in livestock production ($1.68), than in crop production ($1.29), indicating that a better return is received from additional capital spending in livestock. The Grey Wooded soil zone exhibits an almost equal productivity of capital in both sectors.

Marginal labour productivity per week is also slightly lower for livestock than for crops in the Brown soil zone, while it is significantly higher in both the Black and the Grey Wooded soil zones. This is to be expected, since significantly less labour per unit measure of capital is used in livestock than in crop production in the Black and Grey Wooded soil zones. In all zones the level of marginal return on labour in the livestock sector must be judged as low, implying that a measure of underemployment of labour in livestock production also exists here, even if it is not as serious as in the crop sector. This underemployment of labour is particularly evident in the Black and Grey Wooded soil zones.

Regional differences in resource productivity

Some of the differences found between the productivity estimates presented in Table 5 may be due to chance occurrences and therefore the statistical significance of the differences had to be tested. This was done in terms of the standard error of estimates belonging to each elasticity coefficient in the manner followed by

Table 6

Differences in marginal productivities of resources between major soil zones, Prairie Provinces, 1961

Resource and soil zone	Soil zones: Brown and Dark Brown		Black		Grey Wooded	
	elasticity	*t*-value	elasticity	*t*-value	elasticity	*t*-value
Crop production						
Cropland						
Brown and D.B. soil zone	—	—	0.0978	2.86*	0.1144	0.83†
Black soil zone	0.5102	2.86*	—	—	0.7000	2.74*
Grey Wooded soil zone	0.1801	0.83	0.2111	2.74*	—	—
Capital services						
Brown and D.B. soil zone	—	—	1.1450	2.43*	1.3830	3.35*
Black soil zone	0.6330	2.43*	—	—	0.8758	0.12†
Grey Wooded soil zone	0.6144	3.35*	0.7064	0.12†	—	—
Labour						
Brown and D.B. soil zone	—	—	0.4664	1.51**	0.6926	2.06††
Black soil zone	0.0910	1.51**	—	—	0.2033	0.72†
Grey Wooded soil zone	0.0188	2.06††	0.0283	0.72†	—	—
Livestock production						
Capital services						
Brown and D.B. soil zone	—	—	0.9882	0.44†	1.3123	3.01*
Black soil zone	0.8777	0.44†	—	—	1.2470	2.00***
Grey Wooded soil zone	0.6175	3.01*	0.6437	2.00***	—	—
Labour						
Brown and D.B. soil zone	—	—	0.3149	0.33†	0.5139	0.83†
Black soil zone	0.1678	0.33†	—	—	0.3819	0.64†
Grey Wooded soil zone	0.1055	0.83†	0.1482	0.64†	—	—

Note: The table gives the elasticity coefficients necessary to provide marginal productivity of a resource in one soil zone (shown in columns) equal to that in the zone of contrast (shown in rows).

*Significant at .01 probability level
†Nonsignificant at .20 probability level
**Significant at .10 probability level
††Significant at .025 probability level
***Significant at .05 probability level

Heady and Shaw (1954, p. 261). The results of the tests are given in Table 6. The first column in each soil zone gives the elasticity coefficients which would be necessary to provide marginal productivity of a given resource in one soil zone (shown in the column) equal to that in the soil zone of contrast (shown in the rows). This was then compared with the elasticity actually estimated for the resources in Tables 2 and 3, and the significance of the departure was tested. The second column in each soil zone shows the *t* values.

According to this table, an elasticity of 0.5102 would be necessary in the Brown soil zone to provide the $7.49 per acre marginal return on crops which was the estimated return for the Black soil zone (Table 5). Actually the cropland elasticity in the Brown soil zone was found to be 0.0835 (Table 2), giving a marginal product of only $1.22. Testing the difference between the two elasticities in a null hypothesis sense, it was found that it is significant at the 1 per cent probability level. Since different quantities of resources were used in the Black soil zone, it was found that an elasticity of 0.0978 would be enough to give the same marginal product for cropland ($1.22 per acre) as prevails for the Brown soil zone. As was shown in the previous comparison, the difference between this and the actual elasticity of 0.5980 is equally significant statistically.

Comparing other cropland productivities between soil zones (Table 6), it was found that there is also a significant difference between the Black and Grey Wooded soil zones but not between the Brown and Grey Wooded soil zones, even at the probability level of 20 per cent or more.

Differences in marginal returns on crop capital between the Brown and Black soil zones are highly significant at the 1 per cent level, but on livestock capital they are not significant even at the 20 per cent level or better. The superiority of the Brown zone with respect to

investment returns over the Grey soil zone is equally high in both crop and livestock production. There is no significant difference in capital productivity between the Black and Grey Wooded soil zones in crop production, but there is in livestock production at the 5 per cent level. The contrasts are definitely smaller in the livestock than in the crop sector. The temptation to overuse capital in livestock production is also less than in crop production.

In all three zones there are more discrepancies in labour productivity in the crop sector than in the livestock sector where, in fact, no significant departures were found. One reason for this circumstance may be that family labour can be better utilized in livestock production than in crop production. Even in the crop sector some of the departures between the soil zones were significant only at the reduced probability level of 2.5 per cent between the Brown and Grey Wooded and of 10 per cent between the Brown and Black soil zones. Taking the year as a unit measure of time since, of course, labour shortages may develop seasonally, these findings provide evidence that, even under the best of circumstances, underemployment exists on the average farm. There is no significant difference between the Black and Grey Wooded soil zones in this respect; labour productivity here is equally low, demonstrating its overabundant availability.

Productivity and resource prices

The comparison of marginal products with the costs of resources is relevant to the analysis of the resource utilization of the average farm in each soil zone.

For this purpose, elasticity coefficients were computed which would provide marginal products equal to the price of the resource in question. The difference between these hypothetical elasticities and those actually estimated from the production functions for each resource was then tested for statistical significance following the procedure applied by Heady (1954, p. 1075). The results of these tests are given in Table 7.

The price of capital was taken at $1.06 for each dollar, i.e., at 6 per cent interest per year. The average price of labour per person per week was taken at $40.00 in the Brown, $35.00 in the Black and $36.00 in the Grey Wooded soil zone as estimated from census data.

Although marginal products of cropland could have been compared directly with leasing rates prevailing in each soil zone this was not done for two reasons: (1) the rates could not be obtained from census data and (2) in a regionally varying mix, leasing rates may cover not only the use of cropland but also certain equipment or storage facilities. Although the information gathered during field work on the price of land was highly subjective, the term itself is at least not ambiguous. Since it was not possible to compute exact means from these price quotations, the *average price* as used in this study is intuitive and the resultant comparisons highly tentative.

Since land input was measured in physical terms, the *capitalized value* of the marginal

Table 7
Differences between marginal product and market price of resources, Prairie Provinces, 1961

Resource	Soil zones: Brown and Dark Brown elasticity	Brown and Dark Brown *t*-value	Black elasticity	Black *t*-value	Grey Wooded elasticity	Grey Wooded *t*-value
Crop production						
Cropland	0.0631	0.21†	0.3130	2.44*	0.1680	0.86†
Capital services	0.5190	5.51*	0.5955	0.94†	0.7224	1.24†
Labour	0.3998	−0.72†	0.5259	−3.53*	0.8038	−4.94*
Livestock production						
Capital services	0.5519	3.86*	0.5600	2.88*	0.7860	2.21*
Labour	0.3139	−0.66†	0.3852	−1.01†	0.6428	−4.72*

Note: The table gives elasticity coefficients necessary to provide marginal products equal to market price of resource.
*Significant at .01 to .05 probability level
†Nonsignificant at .10 probability level or more

products of cropland can be compared with land prices, the term "capitalized value" being used to indicate the annual value of the marginal product discounted at an assumed rate of 6 per cent. The *capitalized value* of cropland in each soil zone according to Darcovich (1958, p. 89), was obtained by capitalizing $1.22, $7.49 and $2.64 per acre marginal products (Table 5), at 6 per cent interest rates. The results were: $20.30 (Brown), $106.10 (Black) and $44.00 (Grey Wooded). These were compared with the *average price* of land taken as being $15.00 (Brown), $65.00 (Black) and $30.00 (Grey Wooded) soil zones. Testing the departures between elasticities actually estimated from the regression equations and those needed to give marginal products equal to the market price of the land, no significant differences were evident between the Brown and Grey Wooded soil zones. In the Black soil zone, however, cropland productivity, at the 1 per cent probability level, is significantly higher than the price of the cropland itself.

At a probability of 5 per cent or more, marginal returns on livestock capital are significantly higher than the price of capital in all three soil zones. On crop capital, however, it is higher only in the Brown soil zone. In the Black and Grey Wooded soil zones, crop capital yields higher, but not significantly higher, returns than the *price of capital.*

In every soil zone, both the crop and the livestock labour of the average farm yields less marginal return than the price of labour, i.e., all the t values assume negative signs (Table 7). For crop labour, the gap between the two is significant only in the Black and Grey Wooded soil zones, while with respect to livestock labour it is significant only in the Grey Wooded soil zone.

These comparisons suggest that in the Brown soil zone the average farm assumed an equilibrium position in both sectors in regard to the amount of land and labour resources used but not in regard to capital. In the Black soil zone disequilibria existed with respect to land, crop labour and livestock capital. In the Grey Wooded soil zone there was notable disequilibria with regard to crop labour, livestock capital and livestock labour. *A high degree of underutilization of labour and capital is evident from these comparisons.*

PRODUCTIVITY OF RESOURCES AND POPULATION IMBALANCE

In this part of the discussion, an attempt will be made to examine migration from farms in light of the productivity analysis. Areas where returns on agricultural resources are relatively low and where net outmigration has been relatively high in recent times, are considered to have a population imbalance and further adjustments between the population and the resources may be expected in the future. It is, therefore, relevant to identify these areas.

The concept of population imbalance relative to economic resources was formulated in recognition of the fact that migration does not bear a causal relationship to income in any straightforward fashion. It is neither the poorest nor the most prosperous who is the most mobile but rather the person who is relatively prosperous but not prosperous enough, for example, the small commercial farm operator who has a chance to do better elsewhere and who has not only this alternative but also the means to finance the migration. Therefore, areas of low agricultural incomes but with low migration experience in recent times, are not likely to produce large numbers of migrants from the farms in the near future. In this sense, a measure of balance between farm population and resources was probably achieved in these areas through other non-agricultural sources of income.

In this study, two methods have been applied to identify such areas of population imbalance: (1) maps drawn on the basis of simple measures expressing areal variations of incomes and outmigration—where low incomes coincide with high outmigration the population is considered in imbalance; (2) maps drawn on the basis of various mathematical equations predicting incomes and migration—areas where incomes are overpredicted and outmigration underpredicted by the respective performance maps (Thomas, 1960) are designated as having a population imbalance. Each of these two approaches has its merit. Simple measures are easy to compute and the maps compiled from

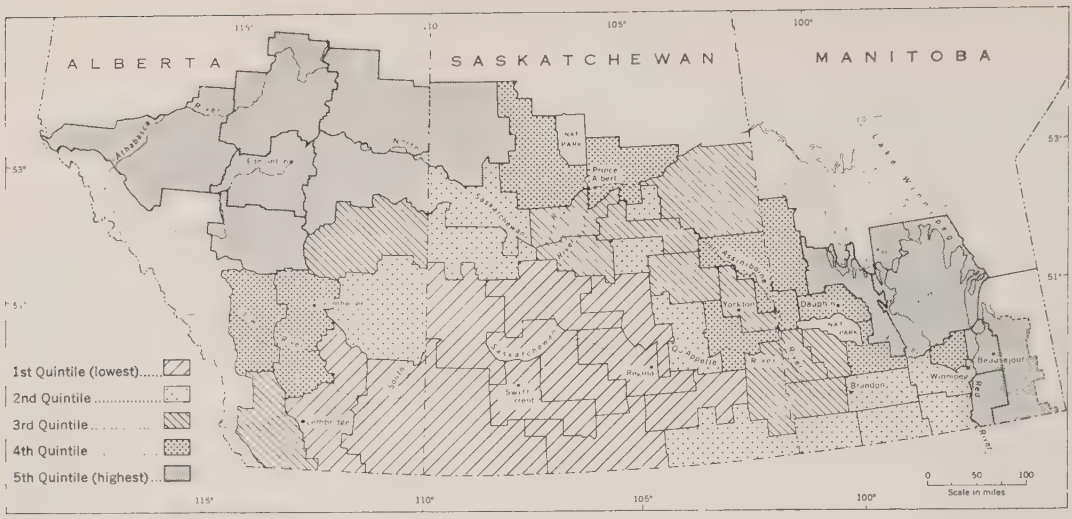

FIGURE 2. Variations of gross incomes from crops expressed in terms of the coefficient of variation σ/Y where Y equals the average crop income for the area and σ is the standard deviation.

them make it easy to identify the problem areas. Of course, further information on income other than that it is low, or on outmigration other than that it is high, cannot be obtained through this approach. The application of performance maps on the other hand is laborious but, in addition to yielding essentially the same results as the previous method, such maps also provide further useful information on the behaviour of the two basic variables: income and outmigration. The following discussion considers a series of maps compiled by using these two methods.

Maps showing, in simple measures, the distribution of gross incomes by crop and livestock production and the intensity of net migration from farms are presented in Figures 2, 3 and 4. Low coefficients indicate high incomes (Figures 2 and 3) and a high degree of depopulation (Figure 4). The legends for these figures were arranged in quintiles so that direct visual comparison could be facilitated. It can be recognized at once that areas of low incomes from both the crop and livestock sectors generally coin-

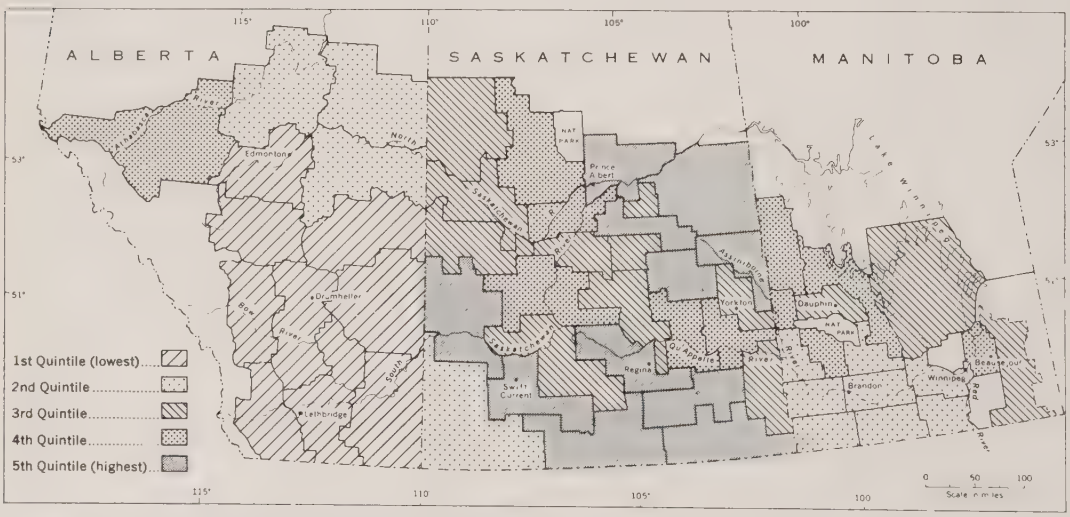

FIGURE 3. Variation of gross incomes from livestock production expressed in terms of the coefficient of variation σ/Y where Y equals the average income from livestock for the area and σ is the standard deviation.

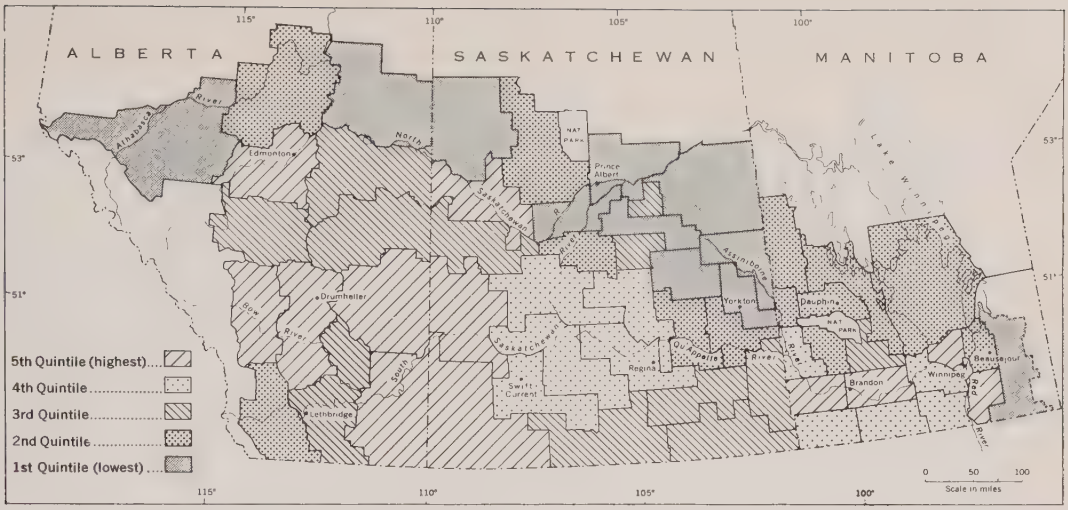

FIGURE 4. Variation in depopulation of farms, *i.e.*, the difference between the *actual* census farm population in 1961 and the *expected* farm population for 1961 which had been computed by adding the estimated births and deducting the estimated deaths from the actual 1951 farm population data.

cide with areas of high migration from farms. This is probably due to the smaller size of farms prevailing in these areas, as well as to such other factors as (1) the poor soil and drainage conditions which result in lower incomes per unit measure of land, and (2) higher density of farm population which survived the economic depression of the 1930's, and thus provides a larger pool of potential migrants in the succeeding decades.

Figures 5 and 6 show those areas where low incomes from crop or livestock production were coincident with high degree of depopulation. There are notable differences between these two maps. Although the whole Grey Wooded soil zone and the northern fringe of the Black soil zone experienced heavy outmigration and although most parts of this region have small crop incomes, some of these areas, Alberta, Census Divisions (C.D.) 12 and 13, Saskatchewan, Areal Divisions (A.D.) 18 and 21 and Manitoba, C.D. 12 and 19, fared reasonably well from livestock production. Other areas show the opposite conditions:

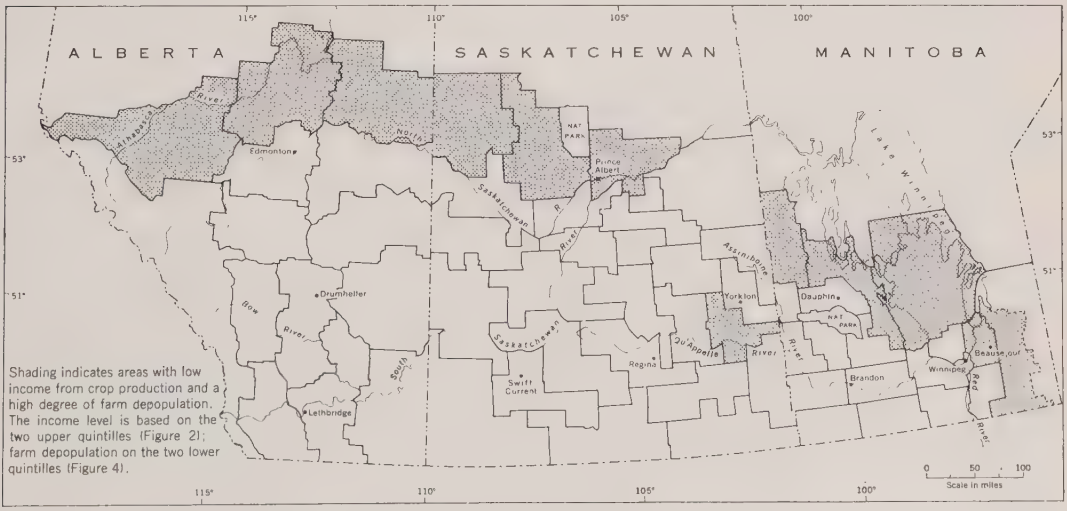

FIGURE 5. Areas with a coincidence of low incomes from crop production and a high degree of outmigration, both being measured in terms of the coefficient of variation.

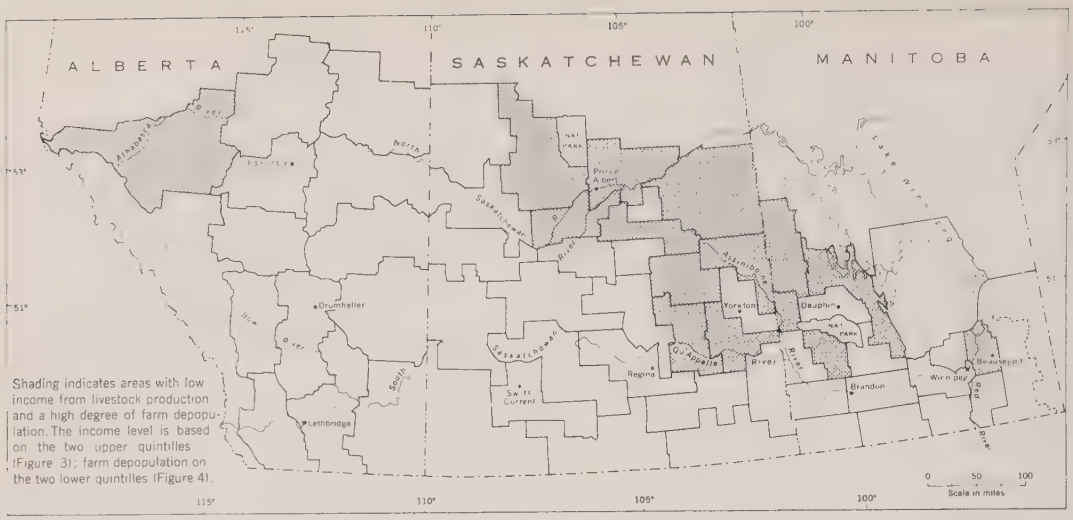
ALBERTA
SASKATCHEWAN
MANITOBA
Shading indicates areas with low income from livestock production and a high degree of farm depopulation. The income level is based on the two upper quintiles (Figure 3); farm depopulation on the two lower quintiles (Figure 4).
Drumheller
Lethbridge
Swift Current
Regina
Yorkton
Dauphin
Brandon
Winnipeg
Scale in miles

FIGURE 6. Areas with coincidence of low incomes from livestock production and a high degree of outmigration, both being measured in terms of the coefficient of variation.

a high degree of outmigration associated with low incomes from livestock production.

The performance maps beginning with Figures 7 and 8 depict areas where incomes from crop and livestock production respectively are either overpredicted or underpredicted in terms of the residuals from the regression $Y\text{-}Y_c/100$. With certain exceptions, these maps do not differ from other maps showing the distribution of incomes in terms of some simple measure. Attention will be focussed on areas which had smaller incomes than predicted from the production functions and which in turn had higher outmigration than estimated on the basis of various models used in the previous study (Szabo, 1965).

PRESENTATION OF DATA AGAINST MIGRATION MODELS DEVISED IN PREVIOUS STUDY

Migration Model I in the previous migration study (Szabo, 1965, p. 195) included variables relevant to the size of the farm such as cropland, part-time farm operators and rented land. Areas which had more outmigrants than

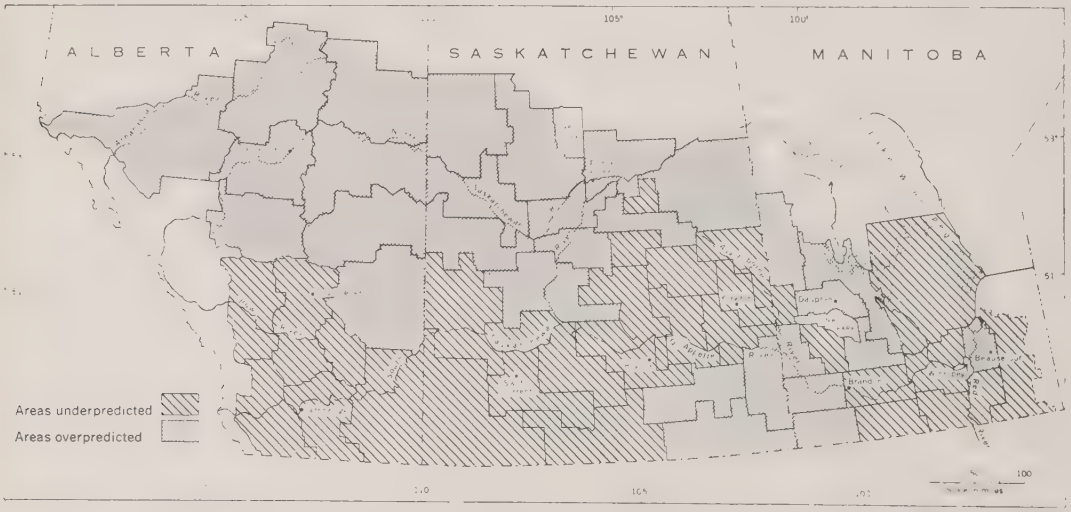

FIGURE 7. Performance map; crop production functions. (Residuals from regression $Y—Y_c/100$.)

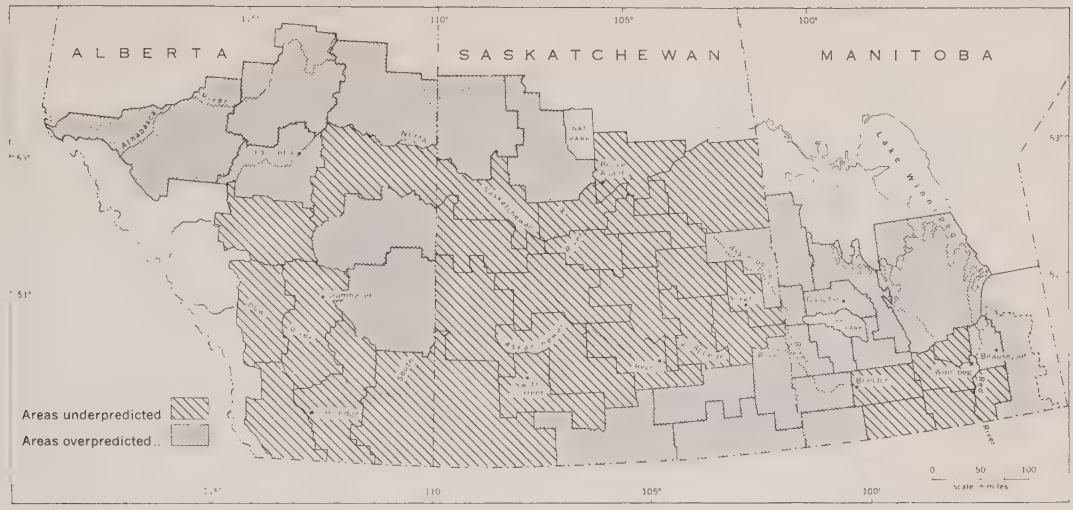

FIGURE 8. Performance map; livestock production functions. (Residuals from regression $Y—Y_c/100$.)

expected on the basis of this model and which had lower incomes from crop or livestock production than expected from the amounts of resources used, are illustrated on Figures 9 and 10. In Figure 9 the low productivity of cropland, together with a moderately underemployed labour supply, is the suspected reason for the problem areas in the Brown soil zone. Wherever locally possible, an increased emphasis on the livestock sector at the present level of labour input is recommended. In areas with *overpredicted livestock* incomes and *underpredicted migration* in this soil zone (Figure 10), oversupply of labour appears to be the single most important factor. Some areas appear on both maps and here labour oversupply in both the crop and livestock sectors and land oversupply, due probably to low quality of land, are associated with relatively high outmigration. In the Black soil zone only one area, Saskatchewan, A.D. 16, had overpredicted livestock incomes and underpredicted depopulation. Where local conditions warrant, reallocation of resources toward the livestock sector could even now improve the population imbalance in this soil zone. According to Model

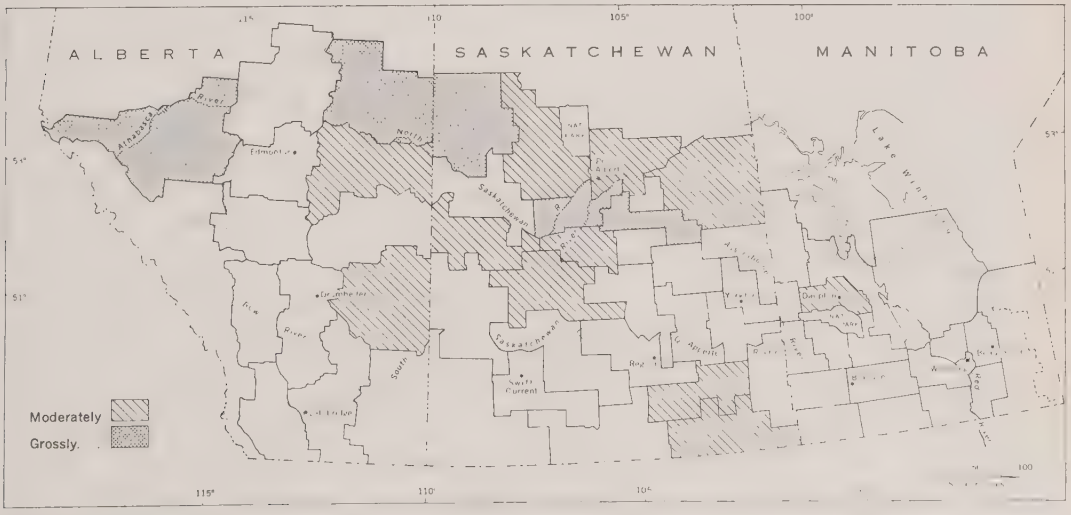

FIGURE 9. Areas with a coincidence of overpredicted crop incomes and underpredicted outmigration on the basis of *Migration Model I* in which the variables included are cropland, part-time farm operators and rented land.

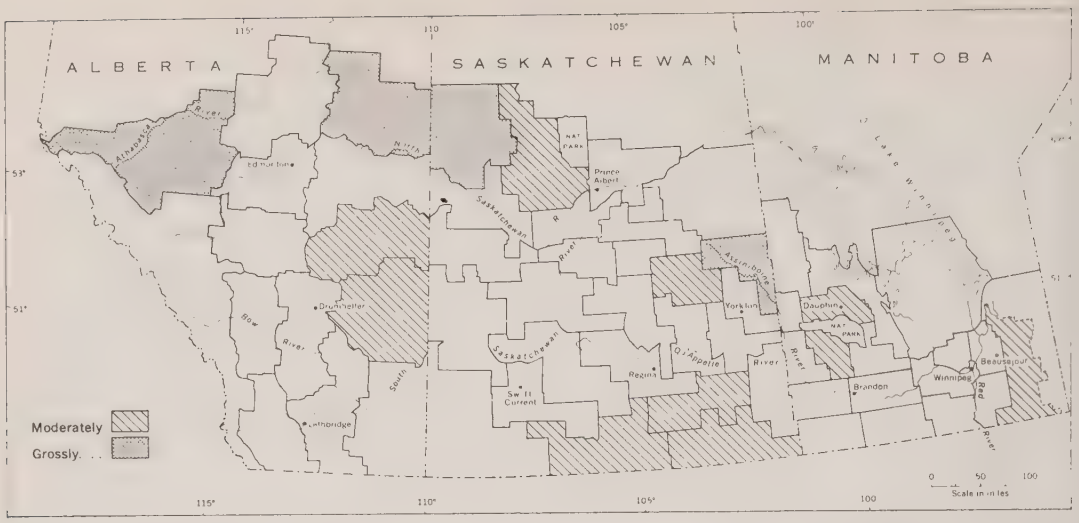

FIGURE 10. Areas with a coincidence of overpredicted livestock incomes and underpredicted outmigration on the basis of *Migration Model I* in which the variables included are cropland, part-time farm operators and rented land.

I the most serious imbalance exists in the Grey Wooded soil zone where a gross oversupply of labour is present in most areas. The productivity of all the resources in both crop and livestock sectors was lowest and depopulation highest in this soil zone. Where either one or the other sector shows promise regarding resources utilization, it is possible to think in terms of reallocation of resources, generally toward the livestock sector. When, however, this alternative does not exist, major dislocations and reorganization of the regional economy appear inevitable.

Migration Model II (Szabo, 1965, p. 196) includes such variables as paid labour, taxes paid and rent paid, which are indicative of operational farm expenditures. Figures 11 and 12 show those areas which had less-than-expected incomes and more-than-expected migration according to this Model. The terms of this Model could identify several areas of population imbalance, which Model I could not, especially in Manitoba. On the other hand, it could not identify certain areas, especially in Saskatchewan, which the previous model discovered. It

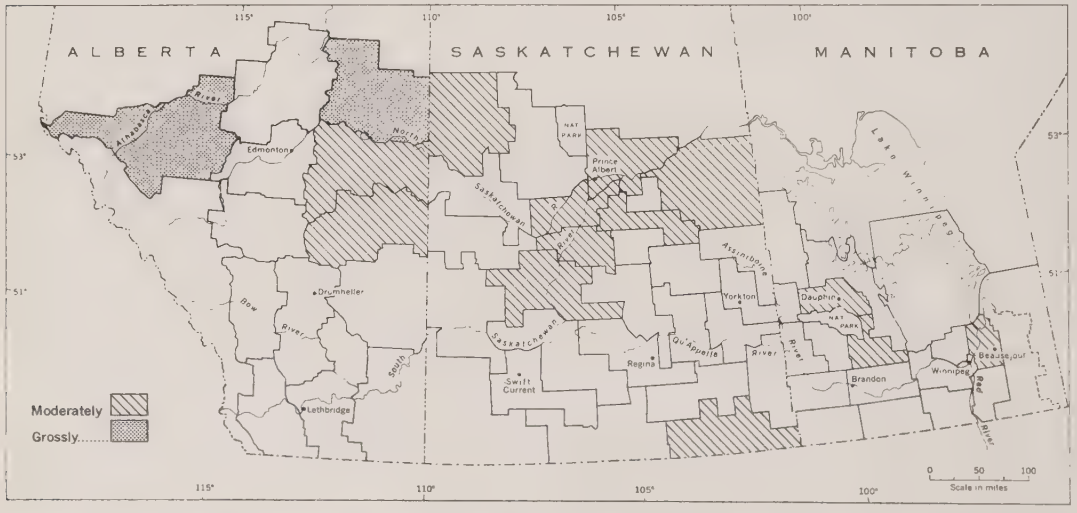

FIGURE 11. Areas with a coincidence of overpredicted crop incomes and underpredicted outmigration on the basis of *Migration Model II* in which the variables included are paid labour, taxes paid and rent paid.

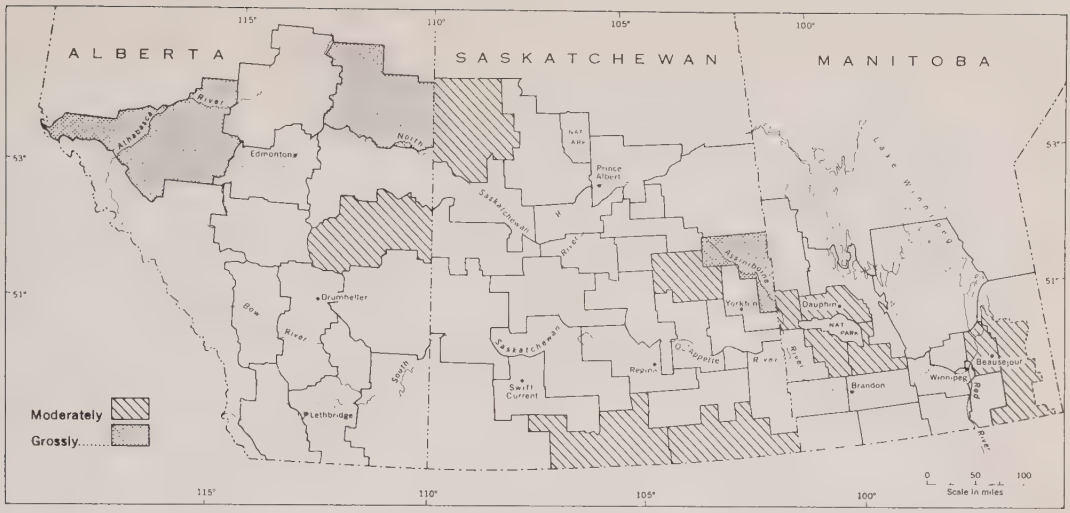

FIGURE 12. Areas with a coincidence of overpredicted livestock incomes and underpredicted outmigration on the basis of *Migration Model II* in which the variables included are paid labour, taxes paid and rent paid.

should be noted that, according to this Model, Manitoba, C.D. 5 had overpredicted incomes from both sectors as well as underpredicted migration—a situation which Model I could not detect. This is of interest, considering that Model II was found to be more powerful ($R^2 = 0.358$) in explaining the areal variations of migration than Model I ($R^2 = 0.287$).

Migration Model III in the previous study (Szabo, 1965, p. 197) includes variables relevant to the size of farm operation in financial rather than in physical terms, i.e., the value of products sold, the return per unit of capital, the capital value of the farm and the value of farm machinery and equipment. The predictive power of this Model ($R^2 = 0.398$) is even higher than those of the previous Models, but, as indicated in Figures 13 and 14, it fails to show even one area as having population imbalance which has not been already identified on the basis of either Model I or Model II. In contrast to this, certain areas of population imbalance were indicated by Model I—Saskatchewan, A.D. 6 and 22 and Alberta, C.D. 4

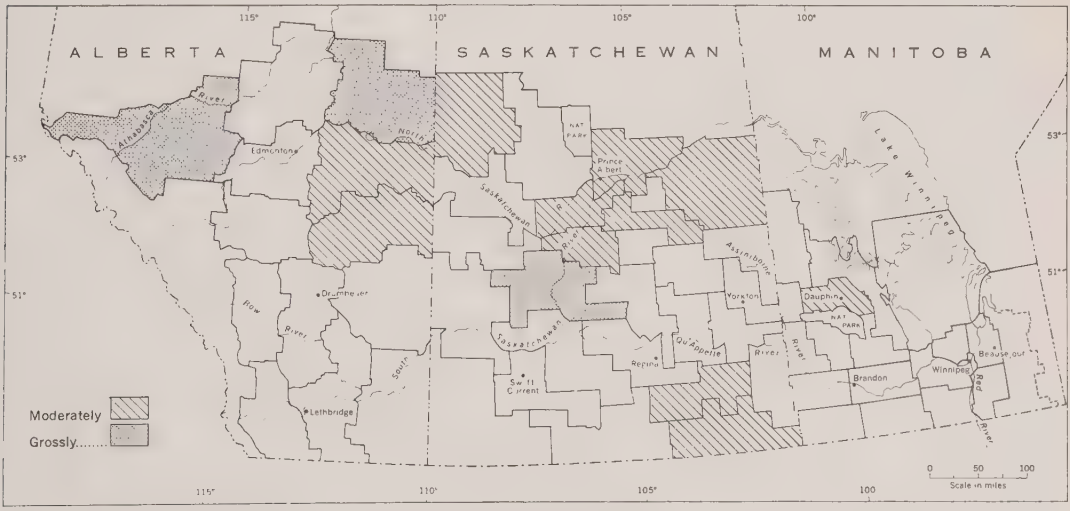

FIGURE 13. Areas with a coincidence of overpredicted crop income and underpredicted outmigration on the basis of *Migration Model III* in which the variables included are the value of products sold, return per unit of capital, capital value of the farm and the value of farm machinery and equipment.

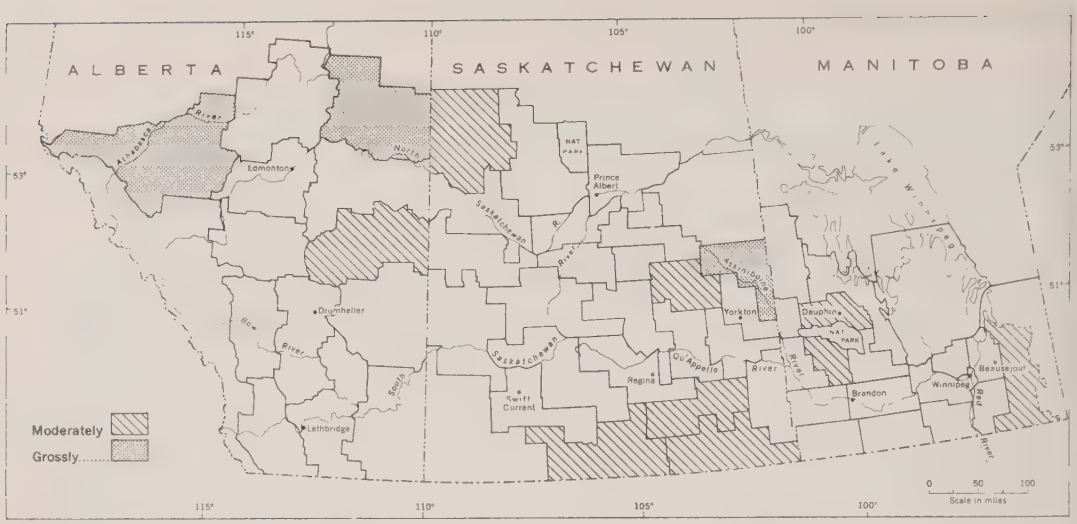

FIGURE 14. Areas with a coincidence of overpredicted livestock income and underpredicted outmigration on the basis of *Migration Model III* in which the variables included are the value of products sold, return per unit of capital, capital value of the farm and the value of farm machinery and equipment.

for crops and Alberta, C.D. 4 for livestock—which both of the successive Models failed to discover.

Migration Model IV (Szabo, 1965, p. 197) with $R^2 = 0.577$, proved to be the most effective in explaining areal variation of outmigration. Here variables indicative of this economic classification of farms were grouped together, for instance, small commercial farms and small-scale farms. Figures 15 and 16 show the areas of overpredicted crop and livestock incomes and underpredicted migration losses derived from Model IV. There is only one area on Figure 15, Alberta, C.D. 6, which was not recognized by any of the preceding Models as having an imbalanced population situation with respect to crop incomes. Since this area was shown on Figure 8 as having an underpredicted livestock income, a reallocation of resources to the livestock sector should work toward easing the imbalance. Another area, Saskatchewan, A.D. 22, with a population imbalance in relation to both crop and livestock income was shown by Model I but not by either II or III.

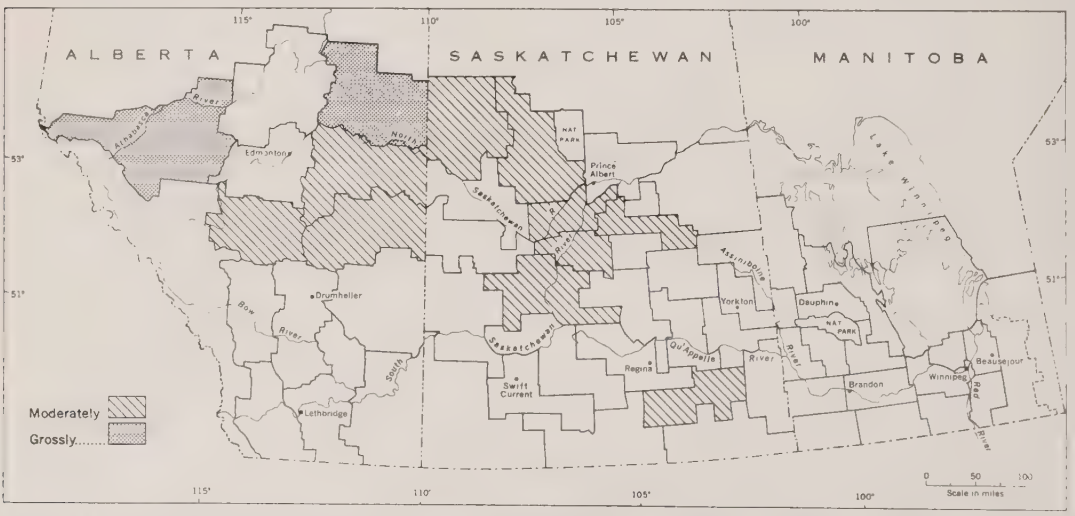

FIGURE 15. Areas with a coincidence of overpredicted crop income and underpredicted outmigration on the basis of *Migration Model IV* in which the variables included are small commercial and small-scale farms.

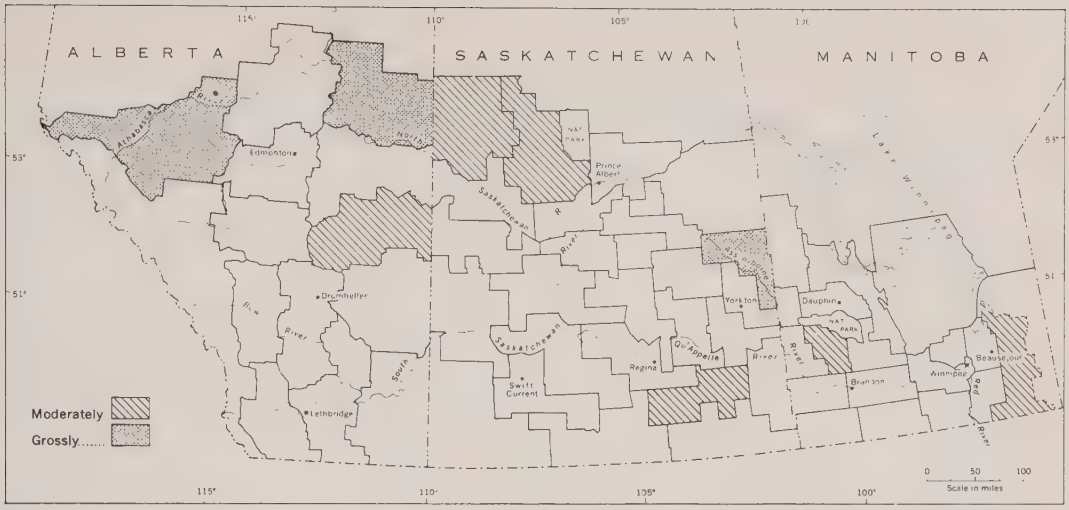

FIGURE 16. Areas with a coincidence of overpredicted livestock income and underpredicted outmigration on the basis of *Migration Model IV* in which the variables included are small commercial and small-scale farms.

This imbalance is confirmed by Model IV (Figures 15 and 16).

When the four most relevant variables were grouped together in *Migration Model V* (Szabo, 1965, p. 198) and their combined effect on outmigration examined, it was found that 62 per cent of the areal variation could be explained by the Model. Areas with overpredicted incomes and underpredicted outmigration according to Model V are shown in Figures 17 and 18. These maps do not show any *new* areas of population imbalance but it is notable that more extensive areas are identified on the basis of crop income than of livestock income, indicating the relevance of an increased emphasis on livestock production where local conditions permit. Areas identified in both Figures 17 and 18 as having overpredicted incomes from both sectors and underpredicted outmigration call for closer examination. These are regions where the present structure of agriculture cannot be maintained because of unproductive utilization of resources. Extensive reorganization of the present structure involving, as it probably will, large-scale outmigration, is the expected consequence of the present

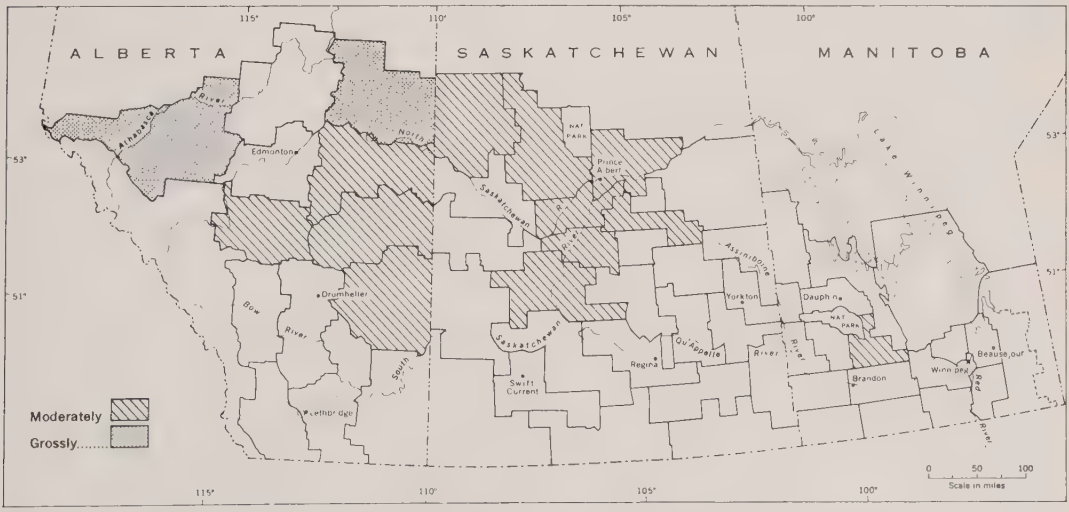

FIGURE 17. Areas with a coincidence of overpredicted crop income and underpredicted outmigration on the basis of *Migration Model V* which includes all the variables considered in Migration Models I to IV.

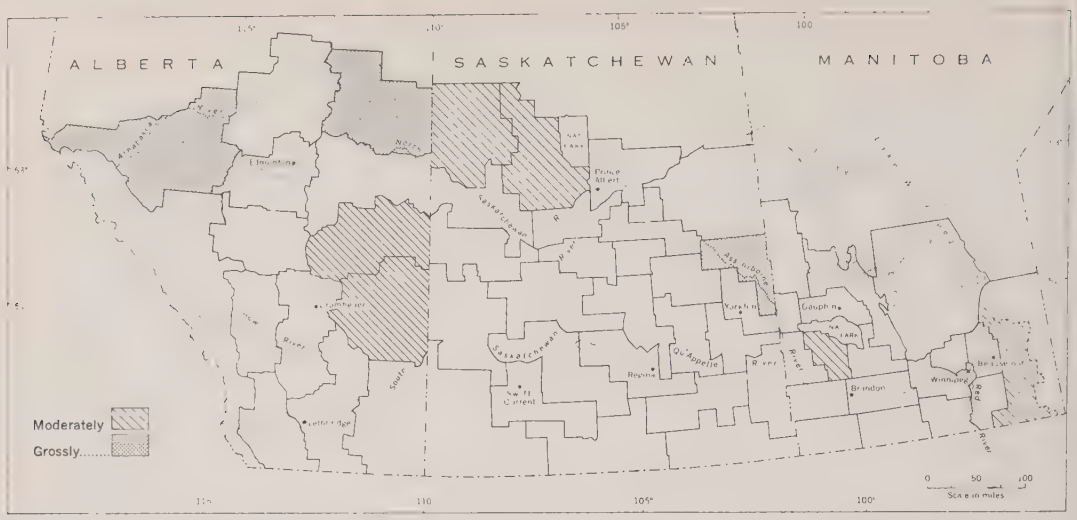

FIGURE 18. Areas with a coincidence of overpredicted livestock income and underpredicted outmigration on the basis of *Migration Model V* which includes all the variables considered in Migration Models I to IV.

economic disequilibrium. This adjustment between the population density on farms and the economic conditions ensuring viability for agriculture must take place, either spontaneously or under a planned program in which the process is understood and influenced. As a result of this the undesirable social developments could be kept to a minimum.

SUMMARY AND CONCLUSIONS

Census data were utilized to compare resource productivity estimates and to relate the results to the off-farm migration history of the Prairie Provinces. Although the productivity estimates are generally acceptable in terms of their broad implications, in many respects they are tentative and require closer scrutiny and further testing. This tentative aspect results from the method of estimation as well as from the criteria by which the variables were selected. A better system of regional disaggregation, more accurate regional price differentials and a system whereby the quality of inputs can be calculated and considered would undoubtedly improve the results. Large farms may use inputs, such as machinery, of considerably better than average quality than do small farms and this may also be true of the management factor which has been entirely disregarded in this analysis. It has also been impractical here to use any weighting system for land quality differentials. A more refined regional stratification of farms might achieve a reasonable homogeneity of land quality. Even if considerably improved productivity estimates were used, it is unlikely that the areas of population imbalance would be significantly different from those identified in this study.

Undoubtedly, migration from farms has been a major factor in the process that has led to the man-land ratio witnessed today. This man-land equalization (Bachmura, 1959, pp. 1013-1016) is now largely concluded in those areas of the Prairies where the land is suitable for modern mechanized agriculture and where the required amount of capital has been accumulated. It is evidently not finished in other parts of the Prairies, and the question confronting the economy is whether or not migration from the farms is the answer to the economic ills of these areas.

Migration presupposes certain conditions: (1) sufficient economic growth in areas absorbing the migrants to provide job opportunities (2) migrants with employable characteristics with regard to age and skills (3) the means to finance migration. If these conditions are met, migration will result in increased incomes for the migrants and not in a transfer of poverty from the rural to the urban scene. The area of outmigration would not benefit economically from the migration unless those remaining have the means to acquire the necessary land and other capital facilities to enlarge their operation

economically. These conditions are more or less satisfied in areas where the man-land equalization process has already taken place. They are apparently not met in those areas where this study has shown a population imbalance relative to the resources used. Many of these people should have migrated long ago but either did not or could not. The spontaneity which worked in other areas failed to bring about the same change here; as a result they exist today as problem areas. Proper understanding of the problem is, however, the first step toward its solution.

ACKNOWLEDGMENTS

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NOTES ON LAND USE AND LANDSCAPE EVALUATION IN A FRINGE AREA OF THE CANADIAN SHIELD

J. W. Maxwell

ABSTRACT

Present-day agricultural land use in a small fringe area of the Canadian Shield in southern Ontario is described against the background of physical features, soil capability and history of settlement. The dynamic character of man's evaluation of land for agricultural use is illustrated. Many farm sites selected by the pioneers are considered by modern agronomists to be unsuited for agriculture. Some areas by-passed by the first settlers are now rated as the best farm lands. Technological advances have brought about a reversal in priorities placed on land evaluation criteria.

RÉSUMÉ

L'auteur décrit l'utilisation actuelle des terres, du point de vue agricole, dans une mince bande en bordure du Bouclier canadien dans le sud de l'Ontario, en tenant compte du relief, des possibilités du sol et de l'histoire de la colonisation. Le caractère dynamique de l'évaluation par l'homme d'une terre agricole y est démontré. Plusieurs terres agricoles sur lesquelles se sont établis les colons sont considérées par les agronomes d'aujourd'hui comme impropres à l'agriculture. Plusieurs régions dédaignées par les colons sont classées maintenant parmi les meilleures terres agricoles. Les progrès technologiques ont apporté un changement dans les priorités établissant les critères d'évaluation des terres.

INTRODUCTION

In the summer of 1963 a Geographical Branch field party carried out land-use mapping in a part of Renfrew County, Ontario containing both rocky uplands and clay plain lowlands. During the course of the work it became apparent that some striking changes have occurred in man's evaluation and use of the upland and lowland areas during the period of settlement. The purpose of this paper is to describe the present pattern of agricultural land use in the area and to relate this pattern to the changes that have occurred in man's evaluation of the land. Observations are restricted to a small area centred on Admaston Township in the southeastern section of Renfrew County (Figure 1).

MS submitted February, 1966.

THE PHYSICAL BASE

The study area is located in the Ottawa Valley where it straddles a series of roughly parallel northwest-trending fault scarps which delimit alternating upland and lowland blocks.* The penetration of the downthrown blocks by waters of the Champlain Sea during deglaciation and the subsequent deposition of sands and clays over much of the lowland surfaces have resulted in the juxtaposition of terrain typical of the Canadian Shield with topography characteristic of the Ottawa-St. Lawrence Lowland.

It is possible to identify many land types in the area (Fraser, 1953; Richards, 1954). The

*Detailed accounts of the geology and physiography of Renfrew County and surrounding territories are found in the following works: Kay, 1942; Satterly, 1944; Wilson, 1946; Chapman and Putnam, 1951; Quinn, 1952; Fraser, 1953; Richards, 1954.

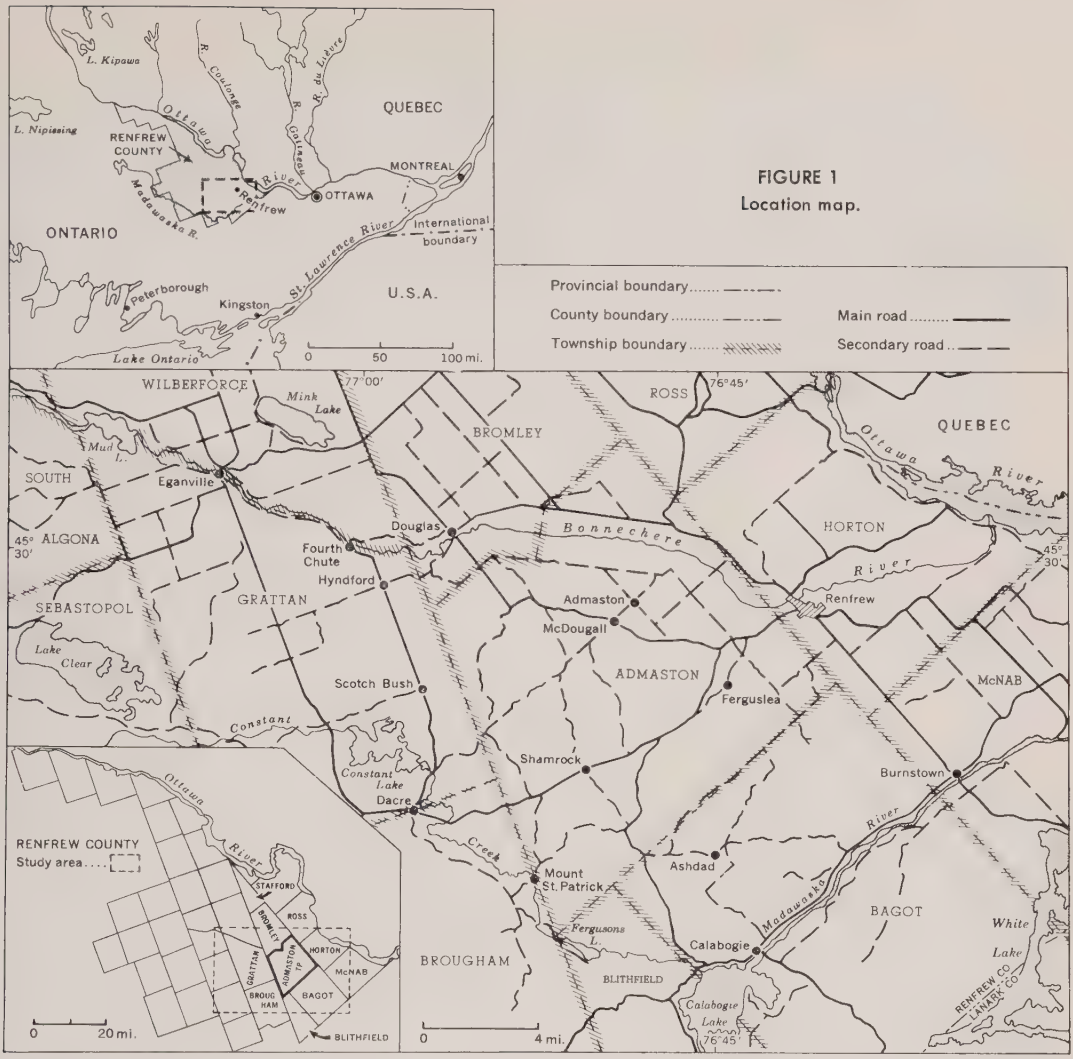

FIGURE 1
Location map.

greatest contrast in physiography and land use, however, is provided by land types characterized by deep clay sedimentation and those not so typified. The lowland area is an almost homogeneous unit dominated by clay plain; the upland, however, represents a land-type complex. Rock-knob topography, although dominant in the upland, is frequently interrupted by other land types including limestone plains and lacustrine sand plains.

The lowland

The area of deep clays is delimited roughly by the 500-foot contour (Figure 2). It coincides closely with the Renfrew Lowland structural unit and is the largest deposit of Champlain Sea clays in the county; it represents a northwestern extension of the Ottawa-St. Lawrence Lowland into the Canadian Shield. Sedimentation has been sufficient to produce a near-level surface, and masks such features as the Douglas fault scarp where it crosses the lowland. The flat surface presents a striking physical contrast to the rock-knob terrain of the Shield surrounding it.

In terms of present-day agriculture in the area, the lowland is the most significant physiographic unit, having soils with the highest agricultural capability ratings in Renfrew County (Figure 3). The flat-lying, stone-free

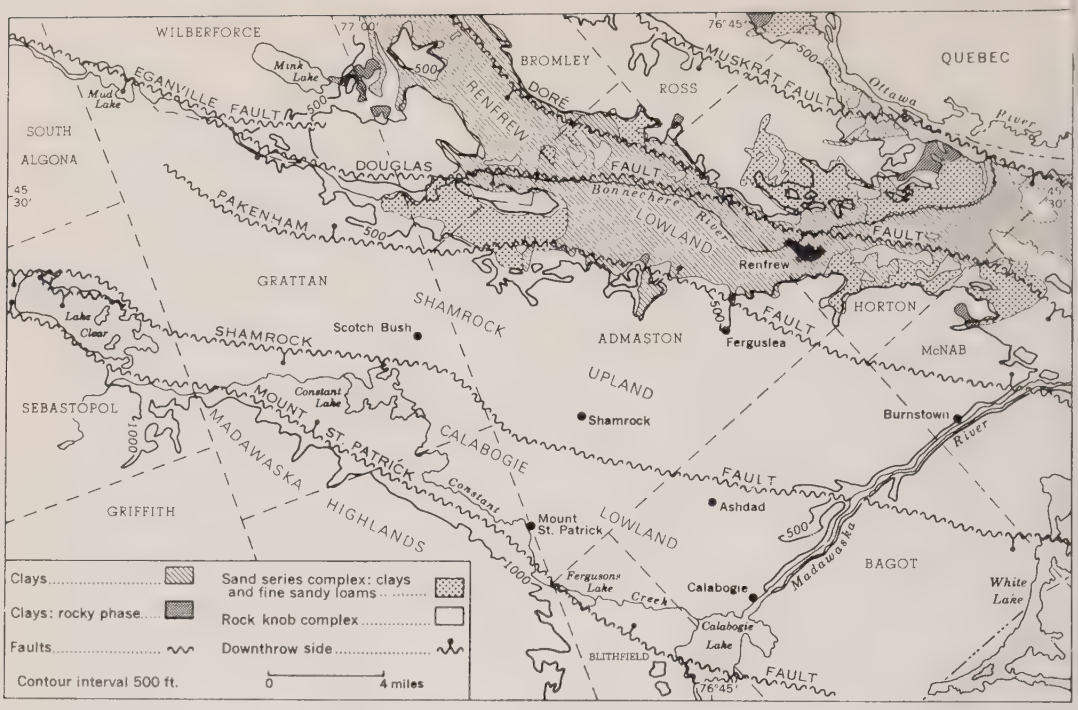

FIGURE 2. Structural units and surficial material (Satterly, 1944; Gillespie, Wicklund and Matthews, 1964).

clay lands offer few obstacles to power machinery. Limitations posed by poor drainage conditions have been largely removed with the introduction of tile drainage. Steep slopes are found only in the small incised stream valleys and along the borders of infrequent Palaeozoic and Precambrian outliers. Undulating topography is confined to occasional areas of sandy-loam deposits, and non-arable land is limited to a few small thinly-mantled outliers of Precambrian rocks and Ordovician limestones.

The upland

The physiographic upland examined in this study lies to the south of the clay plain lowland. Its northern boundary coincides with the southern extent of the clays; in places this boundary follows the Pakenham fault scarp. The southern limit is clearly defined by the Mount St. Patrick scarp which separates the upland from the fault blocks of the Madawaska Highlands. Although structurally this area contains both lowland and upland, the Calabogie Lowland and the Shamrock Upland, terrain conditions are similar throughout as the area escaped deep clay sedimentation. Broken relief, great slope variability, numerous rock outcrops and interrupted drainage mark this terrain as Shield topography. Certain characteristics, however, set it apart from the Madawaska Highlands to the southwest. The upland has a more subdued local relief and contains small outliers of flat-lying Palaeozoic limestones and dolomites not found in the Madawaska Highlands. Moreover, lacustrine sands, outwash materials and glacial till are much more frequent and continuous, particularly in the Calabogie Lowland section.

The soils of this physiographic upland are mainly till-derived, generally shallow and stony. Large parts of the surface have less than 75 per cent soil cover; and stones, varying from one inch to one foot in diameter, can constitute up to one-half the soil body (Gillespie, Wicklund and Matthews, 1964, pp. 40-41). Such soils present severe handicaps for any type of agriculture (Figure 3). Only in the relatively small, infrequent pockets of sandy to gravelly outwash, lacustrine or kame materials or where the till is relatively deep, and stoniness is not

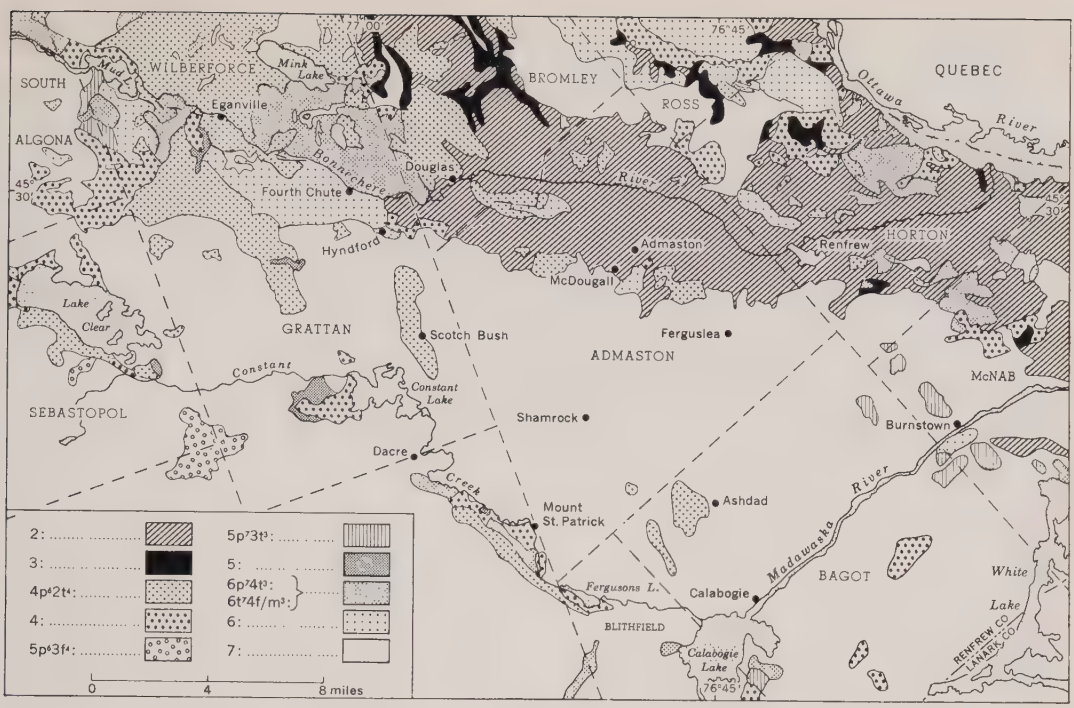

FIGURE 3
SOIL CAPABILITY FOR AGRICULTURE

Soil capability classes:

Class 2—moderate limitations that reduce the choice of crops or require moderate conservation practices.

Class 3—severe limitations that reduce the choice of crops or require special conservation practices.

Class 4—severe limitations that restrict the choice of crops and require special conservation practices or careful management or both.

Class 5—unsuited for cultivated crops except perennial forage crops; responsive to improvement practices.

Class 6—unsuited to cultivation; capable of uses for improved permanent pasture.

Class 7—unsuited for agriculture.

Soil capability subclasses:

Subclasses are divisions within classes, which as a result of soil and climate, have the same kind of dominant limitations for agricultural use.

Twelve different kinds of limitations are recognized to date at the subclass level. Four are found in this area

f — nutrient deficiencies
m— soil moisture deficiencies
p — stoniness
t — topography, slope or pattern

Example of symbolization

$4p^62^4$ Sixty per cent of the area is rated *class 4*; stoniness is a limitation in these soils; 40 per cent of the area is rated *class 2*.

too severe, has agricultural activity become permanently established.

AGRICULTURAL LAND USE

Heavy emphasis is placed on livestock and dairy production in Renfrew County. Eighty-seven per cent of the county's commercial farms* were classified as either livestock or dairy enterprises in the 1961 Census of Agriculture (Dominion Bureau of Statistics, 1963). Consequently, there is little variation in crops —oats, hay, and improved pasture account for 90 per cent of the improved farm acreage. Farming in the study area is similar to that practised elsewhere in the county. In the townships of Grattan and Admaston and the combined townships of Bagot, Blithfield and Brougham,* 86, 88 and 87 per cent respectively of the commercial farms were classified as either livestock or dairy enterprises in 1961

*A commercial farm is defined in the 1961 *Census of Canada* as a farm where the value of agricultural products sold in the twelve-month period preceding the census date is equal to or exceeds $1,200.

*These three townships have been grouped together since, combined, they had only 53 commercial farms in 1961; Admaston Township had 148, and Grattan Township had 76.

FIGURE 4
A partly harvested alfalfa field in the clay plain lowland. A wagon load is being transferred from the forage harvester to a truck for shipment to a local alfalfa dehydration plant.

(DBS, 1961); likewise, oats, hay and improved pasture accounted for 90, 93 and 87 per cent respectively of the improved farm land at the time of the 1961 census.

Almost all commercial farms of Admaston Township are located on the lowland clay plain, whereas the farms in the other townships are in the upland. The fact that there is no significant variation in the distribution of commercial farms by product-type between Admaston and the other townships indicates that physiography has had no bearing on the type of farming practised.

Important differences do exist, however, between upland and lowland farms, and are reflected in farm income. In 1961, 74 per cent of the census farms in Admaston Township were classified as commercial; in Bagot, Blithfield and Brougham, only 56 per cent and in Grattan, 51 per cent of the census farms were

FIGURE 5
A well-maintained lowland pasture is shown in Figure 5.

so classified (DBS, 1961). In the twelve-month period preceding the 1961 census, 23.5 per cent of the census farms in Admaston sold agricultural products exceeding $5,000 in value, but in the upland townships only 4 per cent of the farms were in this category.

The agricultural landscape of the lowland compares favourably with those of most other livestock areas in eastern Ontario. Generally, buildings are in fair to good condition, mechanization is widespread, reasonable animal husbandry is evident and crops look good (Figures 4 and 5). Improved pastures are usually well maintained and practices such as mechanical and strip grazing are frequently employed. Alfalfa and alfalfa mixtures account for 58 per cent of the county's hay acreage. Several modern alfalfa dehydration plants (Figure 6) operate in the lowland and provide a ready market for surplus production.

FIGURE 6. One of the several alfalfa dehydration plants operating near the town of Renfrew. The truck is about to dump a load of freshly harvested alfalfa into the hopper. The alfalfa is dehydrated, chopped and sacked for shipment to feed and food processing plants.

Although many problems beset the lowland farmer, few are unique to the area. Most are related to marketing, cost-price ratios and land acquisition, and are common to all eastern Canadian farmers. There is no doubt that agriculture is a well-established and relatively prosperous activity on the lowland clay plain.

The differences between the agricultural landscapes of the lowland and upland are striking. Most of the upland has not been cleared for farming so that forest rather than cultivated land dominates the landscape. The decaying hamlets and numerous marginal farm-forest operations that characterize the upland provide a great contrast to the busy towns and prosperous lowland farms. They are the mute evidence of a long-standing maladjustment in land utilization. Abandoned farms are everywhere at hand. Upland farms operating on a scale similar to lowland farms are few. They are restricted to the infrequent and isolated pockets where soils have sufficient depth and extent to allow a significant acreage to be tilled. The magnitude of these landscape differences can be estimated by studying the generalized land-use pattern shown in Figure 7.

The limitations presented to agriculture by the upland's physical base are readily observed in Figures 8 to 11. Because of the frequent occurrence of excessively stony and shallow soils, most of the land is non-arable, suitable at best only for rough pasture. The inability to cultivate, seed and fertilize land such as that shown in Figure 8 results in low carrying capacities; this, in turn, has resulted in farmers using bush lots as supplementary pastures (Figure 9). The damage done to young trees by browsing cattle seriously curtails the future productivity of the woodlot, while little nourishment is supplied to the livestock.

The first settlers made great efforts to clear the stones from the fields. This early act of improvement produced one of the main features of the upland landscape, the stone fence (Figure 10). Whereas the pioneer settler viewed the stone fences enclosing his fields as symbols of progress, the present-day farmer sees them as liabilities. Not only do they symbolize the character of his soil, they have become physical obstacles to efficient farming. The small fields which were suited to early ox-powered agriculture must now be consolidated to provide fields of efficient size for power machinery. The heavy labour or expensive custom work required to remove the fences acts as a deterrent in this cash-short area. Consequently, a pattern of small, uneconomic-sized fields prevails in the upland.

Erosion and drought are additional problems in the upland. The prevalence of light-textured and shallow soils and the moderate to steep slopes make soils and yields susceptible to these hazards (Figure 11). Drought susceptibility was clearly illustrated in the 1964 crop year, when extremely dry conditions existed in Renfrew County. Upland crops and pastures

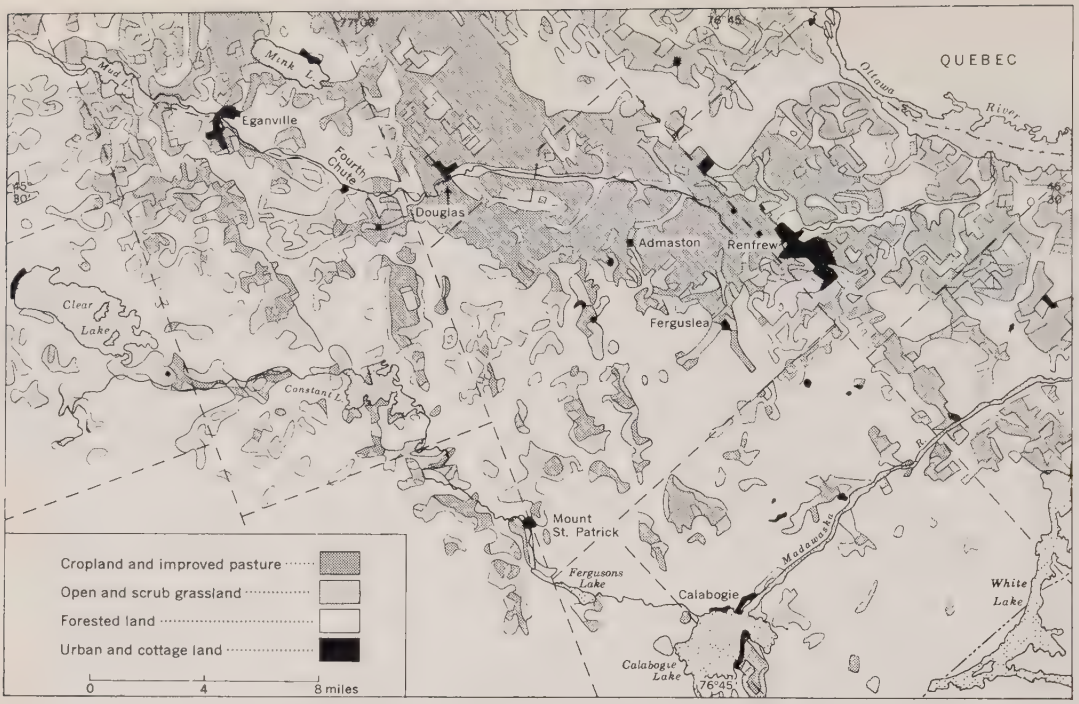

FIGURE 7. Generalized land use, 1963.

showed the results of the dry conditions almost immediately after the onset of dry weather. There was widespread loss of hay and grain crops, and pastures were dried up. While the drought was severe on the lowland clays the effects on crops were not as serious.

The handicap imposed on the upland farmer by terrain conditions has largely precluded effective use of power machinery. This, together with the other disadvantages discussed, has greatly widened the gap in productivity levels between upland and lowland farms. Increasing production costs and low profit margins prevailing for dairy and beef products have placed the upland farmer at a serious disadvantage, condemning him to a low income. The econo-

FIGURE 8
An upland pasture. Although stoniness is not always so excessive, it is always present as a major problem.

FIGURE 9
Bush pasture in upland. The degree of grazing intensity is given by the difference in sward condition inside and outside the highway fence. Small shrubs are absent, having been devoured by the cattle.

mics of this situation are inescapable. Low farm income results in shrinking capital funds and insufficient depreciation allowances, which in turn result in failure to apply commercial fertilizer to impoverished soils, delay in carrying out herd improvements, poor maintenance of fences, buildings and machinery, harvesting of immature timber in the woodlot and, generally, in depreciation of the farm holding. The inevitable consequence, still lower farm income, frequently compels the farmer to seek non-farm work to supplement his income. Less time, therefore, is devoted to the farm operation and farm revenue continues its downward trend. As non-farm income forms an ever-increasing part of total income, interest in the farm often fades until finally the herd is sold and the land is put out on shares or rented for pasture. Often the family will move closer to the non-farm job and leave the farm buildings

FIGURE 10
Stone and rail fence enclosing a pasture on Eganville loam soils at Scotch Bush. Although these soils are the best in the upland, stoniness is still a problem.

FIGURE 11
A relatively good upland field. Jersey cows are pasturing the hay aftermath. Shallow soil (see rock outcrop) and moderate slope make such fields highly susceptible to drought. The fact that Jersey rather than Holstein cows make up the herd, suggests that the farmer has not considered all the economic facts of dairy production.

vacant. As fences break down, soils degenerate and grasses perish, the farm cannot be rented even for pasture. Ultimately, as silvery cinquefoil and juniper choke out the few remaining grass areas, the final stage is reached, the abandoned farm (Figures 12 and 13). This end product of the process is well represented in the upland (Figure 14). As more and more farms reach this stage, community life breaks down, thus accelerating the rate of decline. These

FIGURE 12
Juniper infestation occurs quickly in upland fields when tilling ceases. Once established great effort is required to remove the juniper to make the field tillable again.

FIGURE 13
Abandoned farmstead and field in upland. The field is almost covered with silvery cinquefoil, common mullein and toadflax—indicators of dry, impoverished soils. These weed species frequently occupy entire fields making them of little value for pasturing.

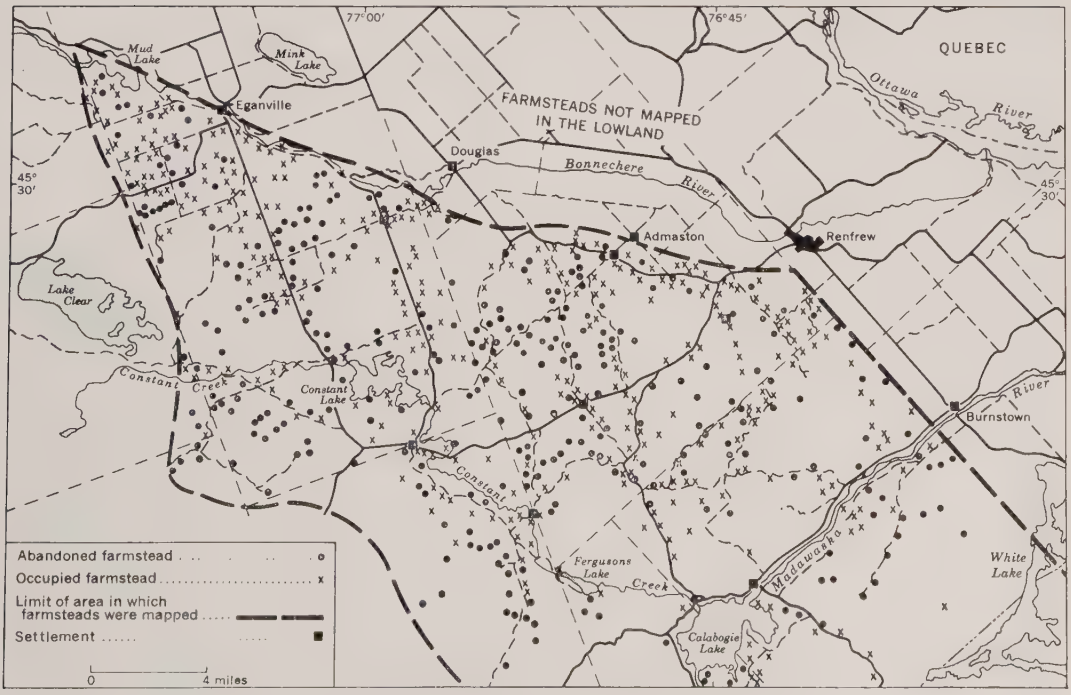

FIGURE 14. Abandoned and occupied farmsteads in upland, 1964.

areas may be termed "twilight zones of agriculture" since not only are the farms in their last days as economic units, but the local population is usually characterized by a high proportion of elderly people. Usually with the beginning of stagnation, the younger segment of the population leaves the area in search of greater opportunities.

SETTLEMENT

Reasons for settlement

The depressing condition of the upland agricultural landscape invites the question, "Why was farming ever attempted on such lands in the first place?" The principal reasons for the original agricultural settlement of the Canadian Shield can be traced to the square-timber trade that developed in Upper Canada during the first decade of the nineteenth century and expanded rapidly thereafter. This trade, based on the white and red pine, led to the establishment of large lumbering operations in the pineries of the Ottawa River basin; the waterways of the basin, down which the timber was driven, reach far into the Canadian Shield.* As the lumbermen penetrated deeper into the Shield country, increasing difficulty was experienced in transporting supplies from the "front" townships on the St. Lawrence to the camps. The rapids of the Ottawa and its tributaries made the journey hazardous; many portages were necessary and resulted in slow and expensive trips. Faced with high freighting expenses, which could double and triple the original costs of supplies (Jones, 1946, p. 111), camp operators encouraged settlers to locate on lands near the "shanties"** so that at least part of the camps' requirements of hay, oats and vegetables could be grown locally.

Settlers were quite willing to co-operate with the lumbermen, for a guaranteed cash market with high prices was a rarity in Upper Canada in the early 1800's. Many settlers placed an exclusive priority on proximity to a shanty when choosing their locations. Too frequently, little or no consideration was given to the ability of the soils to sustain continued agricultural production; consequently, many Shield areas totally unsuited for permanent agriculture were settled. Farms established in such areas could operate profitably for the few years the local shanty operated; however, when pine was exhausted and the lumbermen moved elsewhere, a farmer wholly dependent on the shanty market had little choice but to abandon his farm or operate it at a bare subsistence level. Even if access to outside markets existed, he could not compete effectively with the more favourably-endowed farming areas fronting on the St. Lawrence. On his small acreage of cleared land, he could not produce a large volume of produce at low cost. Wide-scale farm abandonment occurred throughout the pine lands of the Shield with the passing of local square-timber operations.

If the upland landscape under study is interpreted in the light of events of the lumbering era, the reasons for the original agricultural settlement and its subsequent decline appear to become clear. The explanation is indeed accurate for most of the abandoned and agriculturally marginal settlements of the Shield fringe. However, for this particular area, examination of the initial settlement pattern suggests that this explanation is not entirely satisfactory. The pioneers appear to have selected the upland for farm location in preference to the lowland even though access to shanties may have been as good and perhaps better on the lowland. Evidence gathered suggests that the settlers in the study area did give due consideration to the character of the land when locating their farms, and that after considering the flat clay lands along the Bonnechere River as possible farm locations, rejected them in favour of undulating and lighter-textured land on the periphery of the clay plain and well back in the upland.

Before a fully satisfactory explanation for the pioneer settlement of the upland can be obtained an additional factor must be introduced. A striking change has occurred in man's evaluation of the land between the period of first settlement and the present day. Whereas the pioneer classified the upland as the area most suitable for his needs, the present-day agriculturalist rates the lowland clay plain as

*For detailed accounts of the forest exploitation and settlement of the Ottawa Valley and adjacent Shield areas, *see* Lower, 1936, 1938; Jones, 1946; Richards, 1954.

**Lumber camps—from the French "chantiers".

the best agricultural land and considers the upland completely unsuited for farming (Gillespie, Wicklund and Matthews, 1964).

Settlement sequence

Settlers first arrived in the 1820's, attracted by the prospect of sharing in the lucrative shanty market. The area bordered the Ottawa River and had large stands of pine within its boundaries; two important tributaries of the Ottawa, the Bonnechere and Madawaska rivers, traversed it. Both these rivers had large pineries in their watersheds and were used by the lumbermen as carriers in transporting timber to the Ottawa. Consequently, the area commanded a strategic position in the square-timber era.

The first farms were established along the shores of the Ottawa River, it being the only traffic artery connecting the Ottawa Valley to the "outside" in the early period.* Settlement thereafter gradually penetrated inland as the settlers followed the lumbermen into the backcountry of the Ottawa's watershed.

The first farms in the Bonnechere River valley were established at the river's mouth; and, in 1823 or 1824, a farm was located at "Second Chute", the site of the town of Renfrew (Smallfield and Campbell, 1919, p. 1). By 1830, five years after the townships of McNab (est. 1824) and Horton (est. 1826) had been laid out fronting on the Ottawa River, settlement was well established on the Ottawa shore, but the interior was still largely untouched. Alexander Sherriff reported that in 1830 "these townships [McNab and Horton] have a fine bold coast along their whole extent of the Ottawa, on which are some good farms of considerable size; their interior, however, is yet thinly populated. . ." (Sherriff, 1831, p. 249). In the next twenty years, settlement continued to expand in the townships adjacent to the Ottawa. The combined populations of McNab and Horton climbed from 1,326 in 1842 to 2,701 in 1850 and the area under cultivation grew from 5,000 acres in 1845 to more than 8,800 by 1850. The village of Renfrew became a bustling trade centre (Smith, 1851, pp. 334-335).

*Indeed, the Ottawa was still the regular route for supplying the region's shanties as late as 1855 (Jones, 1946, p. 116).

Development in the townships back from the Ottawa lagged behind those fronting on the river. Smith reported that at mid-century Admaston, Bagot and Bromley townships were "little settled", Blithfield was "still less settled", and Stafford "almost unsettled". Brougham and Grattan were just being surveyed. Apparently this situation did not last long, for the geologist Alexander Murray, on doing field work along the Bonnechere in 1853 reported:

> There are many parts of the Bonne-chere country highly capable of cultivation, a great portion of which is already respectably settled, and settlements extend, more or less, the whole way up to within a short distance of Round Lake . . . (Murray, 1857, p. 78).

This brief outline indicates that settlement advanced across the area from east to west. Historical records also indicate that settlement was river-oriented. Not only did the rivers act as main transport routes for lumberman, farmer and trader, they were also the source of power required for the grist, carding and saw mills so important to the local economy.

Theoretical settlement pattern

To illustrate the degree of change that has occurred during the period of settlement in man's evaluation of the physical landscapes, it is useful to compare the actual pattern of first settlement with one that might have developed had the area been settled under present-day conditions. Such a theoretical pattern has been prepared for Admaston Township. Figure 15(a) shows a settlement sequence that would probably be followed in current times, given the constraints that settlement is river-oriented, motivated by a shanty market and progresses from east to west.

The lowland clay plain would be the first area settled. It has the highest soil capability ratings in the county in terms of present-day agriculture (Gillespie, Wicklund and Matthews, 1964), and as the Bonnechere River passes through the centre of the plain, the clay lands would be the first parts of the township encountered by settlers ascending the river. These people would have had to reject consciously the clays before other areas were chosen for farming since additional travel along or away from the Bonnechere would be required to locate on different soil and land types. The

level clay lands near Renfrew (an established centre at the time Admaston was undergoing settlement) would be settled first simply because of their proximity to grist and saw mills, the school, church and marketing-and-supply facilities. With the land near Renfrew occupied, the settlers could be expected to proceed upstream and occupy the remaining part of the clay plain lowland fronting on the Bonnechere. No settlement would be expected to develop in the upland during the first wave of development as large tracts of superior clay land were available, not only in Admaston but in the adjacent townships of Bromley and Stafford. Access to shanties was possible from all these lands so there was no market problem. Even at later stages, the expectation of settlement developing in the upland would be low as nearly all its acreage is classed as unsuitable for agriculture in the present-day land capability classification. In the pattern of settlement that would emerge, only the lowland would be developed for agriculture; the upland would remain as woodland.

Actual settlement pattern

Comparison of Figures 15 (a) and (b) shows that the actual pattern of first settlement conforms with the theoretical only in the eastern part of the township near the village of Renfrew where the clay plains south of the Bonnechere were settled. Initial settlement west of this area did not develop on the extensive clay lands as suggested in the theoretical pattern, but in the contact zone between the clays and the upland. The presence of settlement well back in the upland on soils now considered completely unsuitable for agriculture presents an even greater deviation from the theoretical pattern. That settlement took place on the upland before it did on most of the clay lands, where transportation was available on the Bonnechere to both the shanty markets and the village of Renfrew, indicates that the actual pattern of first settlement has a high negative correlation with the theoretical pattern. The area judged most desirable for agricultural development in the present day was by-passed by the first settlers, and the areas now consider-

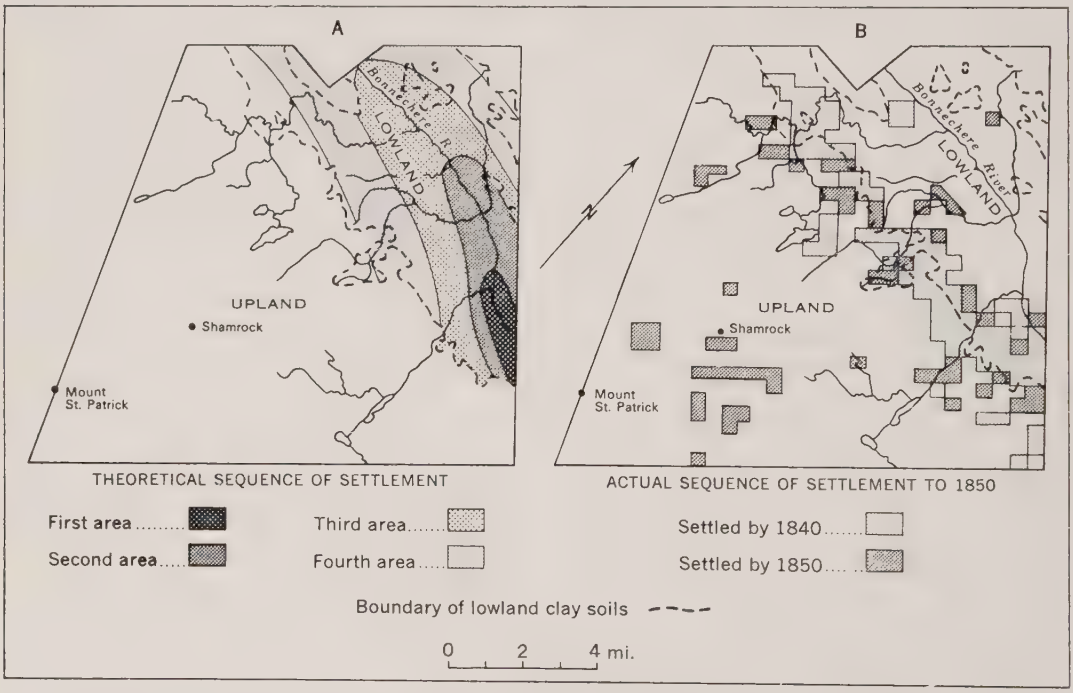

FIGURE 15. Admaston Township.

(a) Theoretical sequence of settlement, based on present-day soil capability ratings and relationship of the area to principal entry routes used by early settlers, i.e., the streams of the Ottawa drainage system.

(b) Actual sequence of settlement to 1850, based on J. Richey's field notes and letters concerning his Admaston survey (1840 a, b, 1841, 1842) and on the Domesday Book, Register, Township Book (1859) and Return of Inspection and Valuation (1872).

ed non-agricultural were selected for farm locations by the pioneers.

Reasons for differences between settlement patterns

Admaston Township's first settlers, being squatters, were not influenced by legal controls when locating their farms; their evaluation of the physical landscape was the key determinant in land selection. In the context of modern agriculture, the land selections made by the pioneers are completely irrational; however, examination of the surveyor's field notes and records of early settlers and travellers indicate that in the context of their times, their decisions were quite rational.

Figure 16 shows the soil conditions in Admaston Township as interpreted by Josias Richey, who surveyed this area between 1839 and 1842. The clays of the lowland are clearly defined as are the sandy and rocky soils of the upland; in general, the map resembles the recently published soil map (Gillespie, Wicklund and Matthews, 1964). In terms of soil ratings, however, some significant differences between the two maps can be detected. For example, nowhere in the areas of Renfrew clay did Richey use the terms "good land" or "pretty good land" in describing soil conditions. These terms were reserved for the description of areas with lighter soils well back within the upland, as well as those along the periphery of the heavy-textured clay plain. Although Richey does not specify that the clay lands were inferior to areas he describes as having "good land", the adjectives frequently used to describe the clays—"low" and "wet"—lead to the inference that the clays were indeed considered inferior to the lighter, better drained loams found on the periphery of the clays and in the upland.

Richey's comments on Admaston's vegetation also provide an insight into the first settlers' assessment of the land. Vegetation was a critical element in land evaluation because, in the absence of soil data, it was used by the settlers to judge agricultural potential. Hardwood trees were generally considered a sign of good land while pine, hemlock and cedar were thought to be indicators of poor land—land that "is

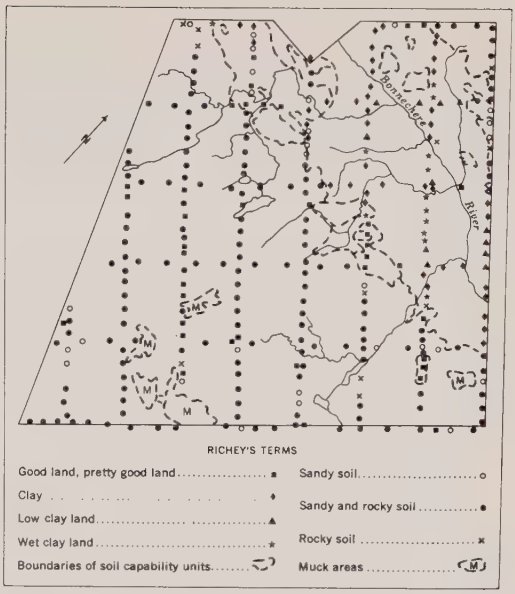

FIGURE 16. Josias Richey's interpretation of soils in Admaston Township, 1842. Plotted from descriptions given in field notes covering the Admaston Township survey (Richey, 1842). Muck areas, after Gillespie *et al.*, 1964.

hardly worth accepting as a present" (quoted by Guillet, 1963, p. 272).

The first settlers in the study area appear to have heeded the popular ideas on association of vegetation type and land productivity. Alexander Sherriff, in commenting on settlement in McNab and Horton townships, noted that

> . . . their interior, however, is yet but thinly peopled, and is commonly reported to contain a great deal of indifferent land. Much, however, of what is now rejected, as I am credibly informed, consists of a serviceable clay soil, principally covered with fir species which will be found acceptable enough when population increases about the river [the Ottawa] (Sherriff, 1831, p. 249).

The fact that the settlers were avoiding the non-hardwood-covered lands led Sherriff to make the following statement:

> It is a common opinion that land without a growth of hard-wood is unworthy of occupation; but this idea, though it may generally hold good farther south, should be entirely lost sight of in exploring these northern parts of Canada. The white pine frequently forms the main growth on excellent clay lands, with but a small mixture of hardwood, and sometimes none whatever. The red pine also well-known to be so abundant on the Ottawa, is by no means so infallible a sign of inferior soil as is generally asserted. It certainly grows to a consider-

able size on almost bare rock, and on arid sands, it is seen in places the sole tree for miles. But it is on strong clays that the red pine is found in the greatest perfection, and here it is usually accompanied with white pine or other firs, and frequently a mixture of hard-wood (Sherriff, 1831, p. 249).

Sherriff's plea for the utilization of pine-covered land appears to have gone largely unheeded; twenty-seven years later, the hardwood lands were still considered the most suitable for agriculture.

All through the Valley of the Ottawa patches of Pine and Hardwood are singularly mingled, and it is a wise dispensation of Providence that they should be so, for as the hardwood land is that which best repays the farmer's toil, so is the Pine Grove the mainstay of the lumberer . . . (French, 1857, p. 27).

The first settlers to enter Admaston Township, like those entering Horton and McNab, would probably seek land covered with fine hardwood stands. Not only were these lands thought to be the most productive, but the hardwood cover when burned provided the farmer with his first cash crop, potash. The vegetation cover of the clay plain did not quite conform to the settlers' requirements. Instead of fine hardwood stands, the settlers found an area recently devastated by fire, the "pine brulee" of pioneer days; burnt windfalls, lying in all directions, littered the plain (Richey, 1842). In place of the pine-dominated forest that once had occupied the plain, a thick undergrowth of "brushwood", mainly poplar and alder, had grown. The fact that at one time the plains had had a coniferous forest cover and was now a tangle of deadfalls and thick underbrush would be sufficient to discourage the settlers from locating on it. In addition, much of the clay plain was poorly drained and even marshy. When asked why their forefathers settled in the upland rather than on the clay plain, the present local inhabitants almost invariably refer to the "late" or "cold" clay soils, the drainage problems and the "unhealthy" aspect of dwelling on the lowland. Today this latter feature cannot be fully appreciated as mosquito control is practised in most settled areas; however, the pioneer had to reckon with the swamp.

The commonest complaints [in Upper Canada] were malarial fever, rheumatism, and ague – the name for variations of what we call the cold or influenza. These were thought to arise from swamps, 'poisonous vapours', and 'the exhalations of decaying vegetable matter', for it was not then known that mosquitoes carried disease germs and were responsible for much more than vicious bites (Guillet, 1963, p. 95).

These conditions, no doubt, spurred the settlers on to examine other landscapes. In considering the adjacent upland area the settler perceived characteristics more to his liking. Hardwood occurred frequently, thereby satisfying the question of land productivity; the soils were lighter and better drained, therefore more easily worked; upland topography allowed the settler to reside on the highest ground to avoid the swamp and "poisonous vapours", yet be near a cedar swamp from which he obtained his rail-fence materials. Unlike clearing operations on the burnt-over clay plain, clearing in the upland yielded a cash crop—potash—from the hardwood ashes. Although most of this upland was unsuited for agriculture, duly noted by Richey (1841, 1842), pockets of relatively deep loams of varying extent were intermixed with the rocky shallow land. Although many of these pockets are too small to support an economic farm unit in the present day, they were adequate for the first settler. With his rudimentary machinery he was limited in the amount of land he could clear and work.

Certain disadvantages were inherent, but they were of little concern to the pioneer; only with the mechanization of agriculture in recent times did they become severe liabilities. Stoniness was the main problem, but it did not deter the settler from working the land; it was considered an annoyance, but not the liability it became later with the introduction of power machinery. When using the hoe, cradle or ox-drawn plow, boulders were easily skirted and tool-damage was held to a minimum.

An indication of the views held on the upland can be gained from descriptions by T. P. French and Alexander Murray. The former, referring to Shield areas served by the Ottawa and Opeongo colonization road which traversed the study area, wrote:

The soil in this part of the Province is a sandy loam, in some places light, but in others deep and rich. The country presents rather a hilly aspect, but by far the larger portion is composed of gently undulating and flat lands. Few of the very highest hills are incapable of cultivation, and it is strange

that the best soil is not unfrequently found on their summits. A good deal of rock and loose surface stone is also to be met with, and while it must not be denied that such often prove a source of much annoyance to the farmer yet they do not prevent the proper cultivation of the land, nor form any great obstacles to the raising of excellent crops . . . (French, 1857, pp. 21-22).

Murray, referring to the country surrounding Kamaniskeg Lake, located in the Shield twenty miles west of Lake Clear where the natural landscape is much more rugged than the upland under study, stated:

Portions of this hard-wood country are highly capable of cultivation, and Mr. Byers . . . has established upon it, at the lower end of the lake, a farm, which, I was informed, yields good crops of oats, hay and potatoes. The surface, on Mr. Byers' farm was at first found to be rather stony, and large boulders would occasionally interrupt the regularity of the plow furrow, but it has been considered worthy of being cleared of these incumbrances, and the stones have been collected and piled in heaps on the fields, probably to be eventually used as fence walls, for the protecting of future crops (Murray, 1857, pp. 81-82).

The factors responsible for the change in land evaluation are the familiar ones associated with agricultural upheaval: mechanization and changing socioeconomic conditions. Mechanization made the upland farm obsolete; slopes were too steep, the small fields too stony and often too irregular in shape; the soils too droughty and fertility too limited. In addition, the farmer, and more particularly his children, were no longer willing to labour long hours removing stones by hand or to labour behind horse and plow when the small returns kept diminishing.

The same factors that made the upland uneconomic for agriculture are responsible for the present relatively high state of agricultural development on the lowland. Mechanization provided the power necessary to deal efficiently with the poorly drained heavy clay soils. With ditching equipment available, a major drainage project was no longer beyond the scope of the individual farmer, and with tractor-drawn equipment the heavy clays could be worked without back-breaking labour.

CONCLUSION

The object of this paper has been to show the importance of treating man's evaluation of land as a variable when analyzing agricultural land utilization.

In the area studied, changes in land evaluation brought about by the revolution in farming technology and the demands for higher levels of living have resulted in much of the land settled by the pioneers being rejected as unsuitable for modern agriculture. Conversely large tracts rejected by the pioneer now contain the finest farms in the area.

The findings of this pilot study are more indicative than conclusive as only one township was examined and the extensive literature on the history of settlement in Ontario was not fully covered. A more comprehensive study covering a larger area and investigating more thoroughly the attitudes of succeeding groups of settlers toward different physical landscapes would be rewarding in terms of the understanding it would produce of man's continuing reassessment and use of the land.

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THREE-DIMENSIONAL VECTOR TECHNIQUE FOR ANALYZING TILL FABRICS: DISCUSSION AND FORTRAN PROGRAM

J. T. Andrews and K. Shimizu

ABSTRACT

A program for a three-dimensional vector analysis of till fabrics is presented for the IBM 1620 and CDC 3100 computer series. Three till samples from northeast England are studied and analyzed by various methods. The samples all belong to the same till lithological unit but the preferred orientation of their pebble '*a*' axes varies considerably within a 3-metre vertical section. Absence of a marked surface of accumulation or a bedding plane within till sheets may result in till fabrics with apparent orthorhombic symmetry if the horizontal plane is used to determine the sense of direction. Selection of other reference planes may show a general unimodal or monoclinic symmetry, i.e., a spherical-normal-distribution. Special problems can result because of pebbles lying transverse, i.e., in the '*B*' lineation, but these distributions can be analyzed separately.

RÉSUMÉ

L'orientation des cailloux dans un «till fabric» est soumise à une analyse vectorielle à trois dimensions. Le programme d'analyse décrit dans le présent article est conçu pour les ordinatrices IBM 1620 et CDC 3100. Les auteurs analysent, à l'aide de différents procédés, trois échantillons de till provenant du nord-est de l'Angleterre. Tous les échantillons appartiennent à une même unité lithologique de till; cependant, l'orientation dominante de l'axe des «*a*» des cailloux, varie de façon appréciable du haut en bas d'une coupe verticale de trois mètres. En l'absence de surface d'accumulation ou de plan de stratification bien identifié, si on utilise l'horizontal comme surface de référence il peut en résulter une orientation apparente à symétrie orthorhombique. Le choix d'autres plans peut donner une symétrie unimondiale ou monoclinique, c'est-à-dire une distribution sphérique normale. Des difficultés particulières peuvent résulter du fait que des cailloux gisent en travers de la direction du mouvement glaciaire, c'est-à-dire en direction «*B*», mais cette répartition peut s'analyser séparément.

INTRODUCTION

Till fabric analysis as a technique for interpreting the genesis of till sheets or of constructional glacial forms has not progressed noticeably beyond the statement regarding the mechanics made in the now classic paper of Holmes (1941) or those contained in the provocative paper by Harrison (1957) in which he demonstrated the importance of adequate statistical manipulation of fabric data and suggested alternative modes of till deposition. Till fabrics have, up to the present, been used almost exclusively to demonstrate or differentiate regional directions of ice movement and their use in the interpretation of till genesis and subglacial processes have not yet been adequately developed. In this sense, methods of till fabric analyses have developed more as techniques based essentially on intuitive reasoning than on proven physical relationships.

There is a considerable body of literature dealing with sampling procedures and statistics but these have not yet been applied to till fabric sampling. Data are more often presented as rose diagrams, the modal group reproducing the direction of ice movement. Calculations by one of the present authors on 250 fabrics, however, have indicated that, for single fabrics and

MS submitted February, 1966.

single sites, the standard deviation of a 0 to 179-degree distribution lies between ± 20 to ± 50 degrees, suggesting that estimations of regional variations of ice flow based on such evidence must be considered with caution.

A major source of potential error lies in the common approach of one-sample—one-site and thus the question of variability within- and between-sites has not been fully investigated. Implicit in many papers dealing with the directional properties of till fabrics is the assumption that sample variance is homogeneous within a single till sheet and that shifts in preferred orientation of sample distributions are insignificant. This study shows that this may not be the case, a possibility which was demonstrated by Kauranne (1960) who indicated that the reproducibility of till fabrics was not constant over distances greater than tens of metres. These results indicate that the directional transport in the till matrix during deposition may vary even within a limited area and this raises the problem of determining by what processes the orientation of pebbles are achieved.

Another problem which applies particularly to till deposits as opposed to fabrics from other materials such as river sediments, is to determine the plane in which the till sheets should be analyzed. The unstratified, rather homogeneous nature of individual till sheets has led to the adoption of the horizontal plane as the one which correctly designates the directional sense of pebble dip, but this convention should not be accepted uncritically. In theory, till pebbles respond to flow or movement by aligning themselves parallel to the transport vector and by dipping into the current. Pebbles lying parallel to the ice movement may be described as lying in the *A* lineation while those transverse to the direction of flow are described as lying in the *B* lineation. The angle of dip relative to a horizontal position is determined by the dip of the surface of accumulation; this is easily seen and recognized in sand bodies (Potter and Pettijohn, 1963) but cannot be seen in till sheets. If the line movement is essentially horizontal then the

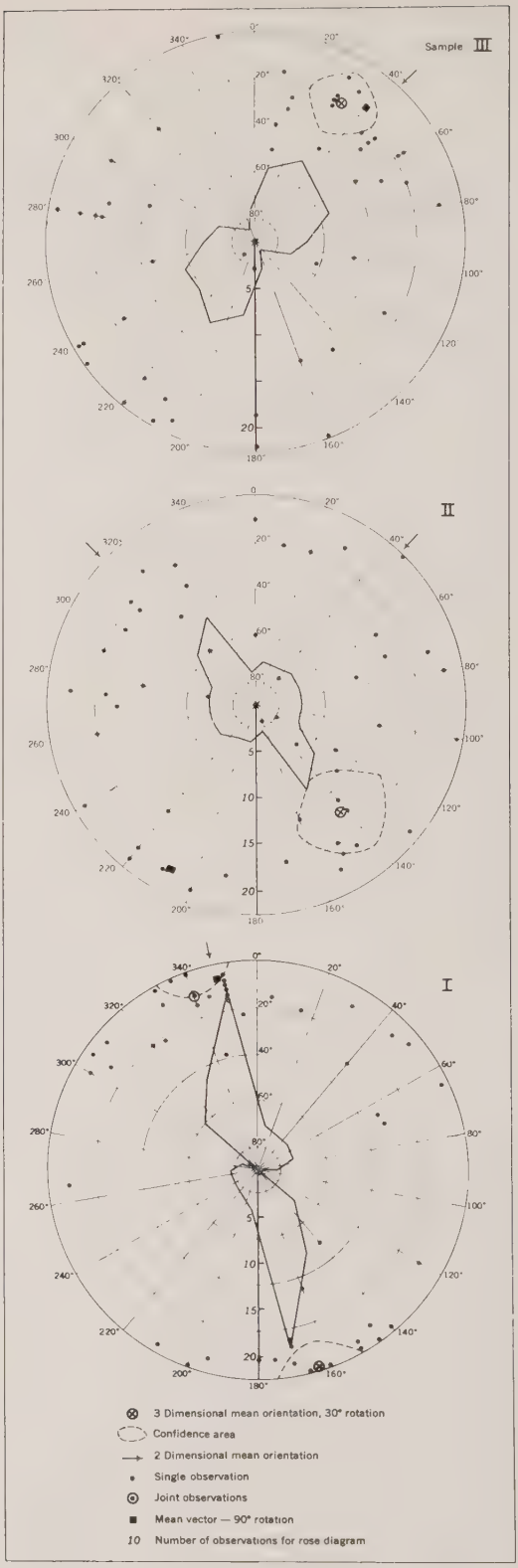

FIGURE 1. Polar equidistant projection with *x* and *y* axes horizontal and *z* axis vertical showing also a mirror image rose diagram of the data. Also included are the positions of the mean vector after a 30-degree and a 90-degree rotation. Number of observations (N) is 50 per sample.

fabric will show monoclinic symmetry if plotted on a polar projection (Harrison, 1957).* If, however, there was a subglacial slope during deposition or if some other such condition has exerted an influence, then the use of the horizontal plane could result in a misleading interpretation. Failure to select the correct reference plane and to rotate the data accordingly probably accounts for most, if not all, of the analyses of till fabrics showing orthorhombic symmetry.

To overcome this problem the three-dimensional vector method of analysis is proposed. This type of analysis is illustrated by examination and discussion of three fabrics of basal till from a cliff sequence at Upgang in northeast England. The samples (I, II and III) were taken at vertical distances of 0 to 0.6, 0.7 to 1.2 and 2.0 to 2.8 metres respectively, above the bedrock/till contact and were all within the same lithological and stratigraphic unit. Fifty pebbles were measured at each site and the orientation and dip of their '*a*' axes was measured to an accuracy $\pm$ 5 degrees. The results shown in Figure 1 suggest that the initial movement of ice into the areas came from the northwest (sample I) and was later followed by flow from the northeast (sample III). The middle sample has a dispersed fabric with a suggestion of two modes from both these directions. Figure 1 indicates that no sample possesses monoclinic symmetry and suggests orthorhombic symmetry instead. The distributions limit the effectiveness of statistical tests which examine orientation for the full 360-degree range. If equally developed opposing modes exist, preferred two-dimensional or three-dimensional vector orientations will lie, not through the opposing modal groups, but in an intermediate orientation. By rotation of the data the spread of results can be minimized; the observations then tend to group as spherical-normal-distributions (compare Figure 1 with Figures 2, 3 and 4).

The majority of till fabric diagrams are presented with the N-S and E-W axes horizontal and the third, or *z* axis, vertical (Figure 1). If

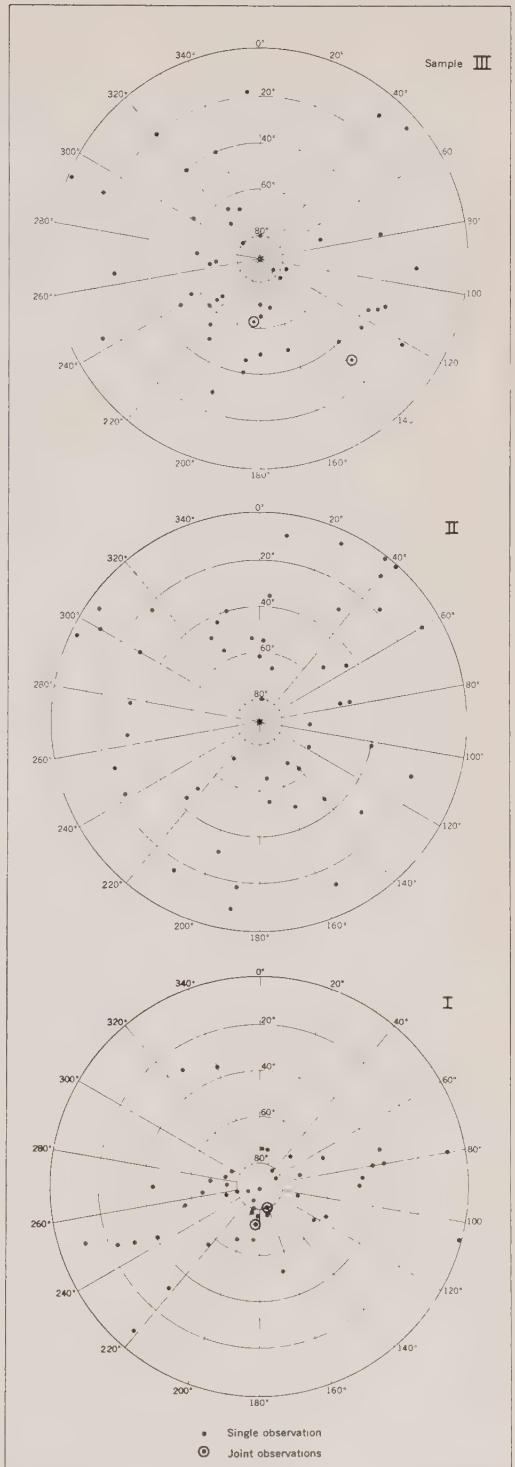

FIGURE 2. Polar equidistant projection of samples after a 90-degree rotation with z and y axes horizontal, and x axis vertical; the pole represents horizontal pebbles.

Monoclinic and *orthorhombic* symmetry are concepts and expressions from crystallography and structural geology. The former implies a maximum peak parallel to the *A* lineation, with or without transverse peaks; the latter describes a fabric possessing two diametrically opposed modes.

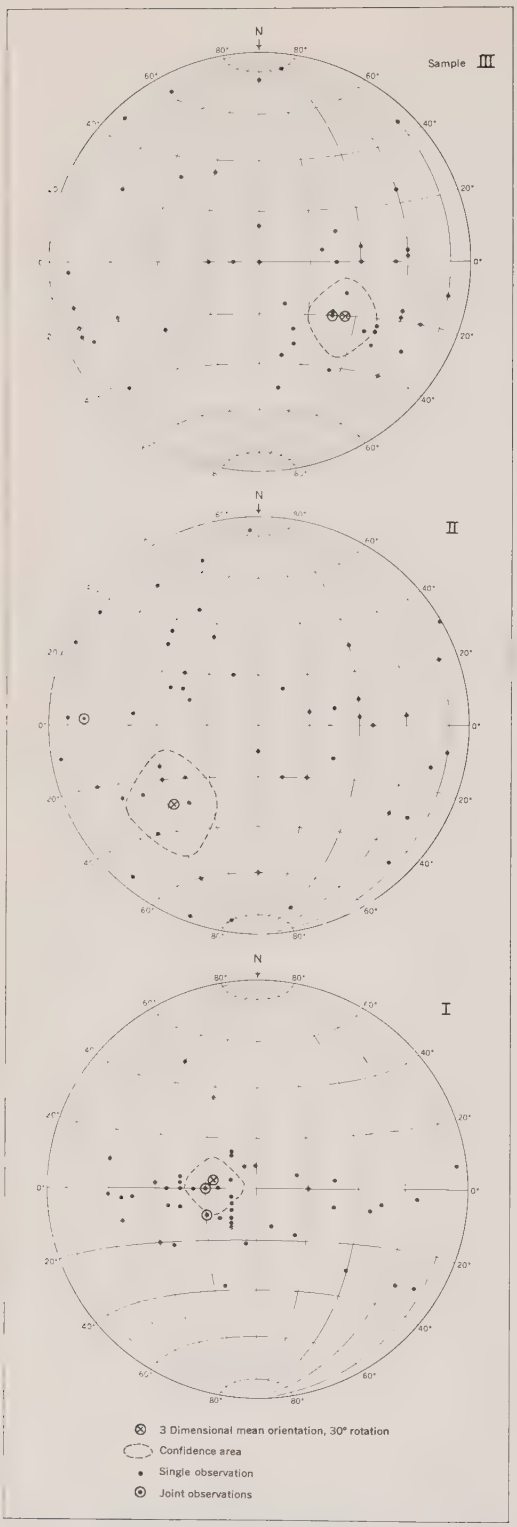

FIGURE 3. Equal-area equatorial projection with y axis vertical and x and z axes horizontal.

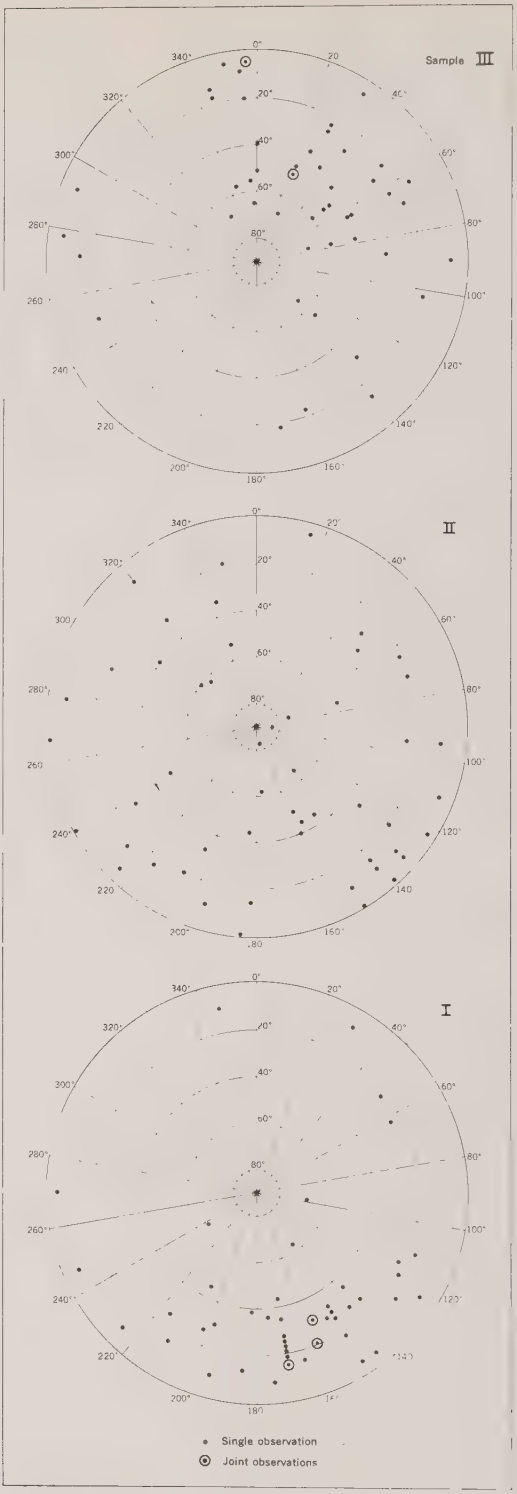

FIGURE 4. Polar equidistant projection with samples plotted after a rotation of 30 degrees.

the data are projected onto a co-ordinate system in which the z and y axes are horizontal and the x axis is vertical then a noticeable improvement is evident, resulting in a single cluster which should lead to a value for vector magnitude close to its maximum, i.e., equal to the sample size. It should be noted that the rotation is equivalent to an orthogonal transformation of the original frame of reference where the x and y axes are horizontal and the z axis is vertical. With such a transformation, angles between individual pebbles and their position with respect to the mean axis are not changed and as a result, if the final results are reported in terms applicable to the horizontal plan, location of the mean axis is independent of the transformation. Rotation of the till fabrics requires that the observations be plotted and that the new positions after rotation be determined by the standard use of the stereonet (Philips, 1963, p. 28).

Because of the problems just discussed and the experimental difficulties encountered, the exchange of quantitative information on till fabric dispersion has been limited up to the present and is not yet comparable to that available for either cross-bedding or sand fabrics. Notable exceptions are the papers by Harrison (1957), Kirby (1961), Kauranne (1960) and Andrews and Smithson (1966). Lack of basic information on the characteristics of till fabric dispersion has led to a neglect of comparative studies of till deposits. The problem of accurately determining orientation and dip may be important, although if the measuring errors are randomly spread throughout the sample, as is generally assumed, this should not be critical.

This paper outlines a three-dimensional vector technique and its application to till fabric analysis and discusses some of the problems involved in interpretation. It also discusses the suitability of using the three-dimensional vector method in such analyses and indicates the variability of direction which may be shown to occur within limited areas.

METHOD OF ANALYSIS

One of the major tasks involved in quantifying till fabric data is the rather mundane and time-consuming work of completing and compiling the numerical calculations required for the analysis. Several methods are acceptable: Harrison (1957) used the Tukey chi-square test which Durand and Greenwood (1958) show to be equivalent to the two-dimensional vector test. Krumbein (1939) and Curray (1956) discuss techniques in which vector magnitude ($L\%$) is highly correlated with the standard deviation, suggesting that they are closely related. Tukey chi-square and two-dimensional vector analysis determine the mean orientation and both produce a measure of the dispersion around the preferred orientation. The distribution can be tested against a null hypothesis of uniformity (Tukey chi-square) or randomness (vector analysis). These results are not influenced by origin, whereas the arithmetic mean can be changed by azimuth rotation. Steinmetz (1962) has given a comprehensive review of these and other tests.

Watson and Irving (1957) employed a three-dimensional vector test to determine the significance of palaeomagnetic data and it was also applied by Steinmetz (1962) to geological studies. The method of computing the mean axis of the pebble a axes for strongly dispersed observations consists in assigning unity to each individual vector, in projecting each unit vector onto three orthogonal axes of reference (x, y, and z), and in adding the projections of the unit vectors to give both the orientation and dip of the mean vector as well as the vector strength (R). There has been discussion recently as to the validity of employing this technique for the analysis of data which contains considerable site variability (Green, 1964). Steinmetz (1964), however, notes that, in the natural sciences, assumptions have to be made on the form of the distributions and the results must be interpreted in the light of the subject matter.

The three-dimensional vector tests have been experimentally adopted for till fabric analysis and a FORTRAN computer program has been developed (*see* Appendix). Initially, two programs were involved, the second using the output of the first, the calculations being performed on the IBM 1620. The revised single-phase program is now available for the CDC 3100 computer series.

The output from the computer program gives a resultant vector or mean orientation, a value for dip which, together with the preferred

orientation, provides the point of balance, vector strength R and the value for R-N where N is the number of observations in the sample. The R value can be tested against the null hypothesis for randomness by using a formula proposed by Watson (1956) which is successfully approximated by the equation

$$R_{95} = \sqrt{\frac{N\chi^2_{95}}{3}} \qquad (1)$$

where χ^2_{95} is the value for chi-square with 3 degrees of freedom and N is the number of observations in the sample. For N equal to 50 the value for R should be above 11.39 at the 95 per cent level. Steinmetz (1962) discussed fully the use and implication of these results. It should be pointed out, however, that R does not necessarily measure dispersion around the mean and thus imposes some disadvantages upon analysis.

As already stated, in calculating the 95 per cent field of confidence surrounding the mean orientation and centre of balance, the second program uses the output of the first. Further, it calculates the statistic referred to as *the estimate of precision parameter* (Fisher, 1953; Watson, 1956 and Steinmetz, 1962). The equation used for this is

$$k = \frac{(N-1)}{(N-R)} \qquad (2)$$

This statistic k, measures *homogeneity of variance* and can be tested by the maximum F ratio (Hartley, 1950) where the degrees of freedom are 2 $(N-1)$ and all samples have an equal number of observations.

The next step (Watson and Irving, 1957) tests whether or not the mean directions of populations are identical. The statistic with degrees of freedom equal to $(p-1)\ (q-1)\ /\ (p-1)\ (N'-q)$ is

$$F = \frac{(N'-q)}{(q-1)} \cdot \frac{\Sigma \mathrm{Ri} - \mathrm{R}}{N' - Ri} \qquad (3)$$

where N' is the total number of observations, q is the number of samples, ΣRi is the sum of the R values for each sample, R the combined value for N' observations, and p number of dimensions.

The problem of deriving a mean orientation for till fabrics is a real one regardless of method used and it must be emphasized that the fundamental reason for supplying the above program is to test till fabric data against a spherical-normal distribution. As Green (1964) states, this imposes a restriction on the use of the statistics, especially as most fabric patterns from till sheets may be bimodal on a horizontal plane. To date, examination of the results derived from the use of the above method of analysis indicates that it has considerable application to studies of the present type.

The approach to the analysis of the computer results is best seen through the series of progressive steps listed below:

(1) Obtain till fabric data and feed it into the computer program.

(2) Test the hypothesis that the three-dimensional distribution is random by evaluating R against an acceptable confidence level, e.g., 90, 95 or 99 per cent.

(3) Accept or reject the null hypothesis; if "accept" the analysis must stop, if "reject" the analysis proceeds to (4).

(4) Plot the values for orientation and dip as well as the limits of the confidence area which has been determined prior to the analysis. This involves rerotation if rotation has already been applied to the observations.

(5) Ascertain whether the sample approximates a spherical-normal distribution, the *lower limit of acceptance* of this hypothesis being $k \geq 3$. If it does not approximate a spherical-normal distribution, then the analysis must cease or an attempt be made to improve the value of k by rotation of the data. Implicit in this *lower limit of acceptance* is the fact that, with k equal to 3 for 95 per cent of the time, observations will lie within a radius of $\pm$ 90 degrees about the mean vector. As k increases this limit becomes smaller.

(6) Examine other samples in the same manner and compare the results by use of the maximum F test (*see* above). If variance is homogeneous proceed to (7).

(7) Use the F test to ascertain if sample orientations belong to the same parent population.

(8) Use the results in an analysis of variance design to determine precision parameters $\hat{\omega}$ and $\hat{\beta}$ (Watson and Irving, 1957).

TWO-DIMENSIONAL ANALYSIS

In the two-dimensional analysis several techniques may be used, Figure 5 illustrating one

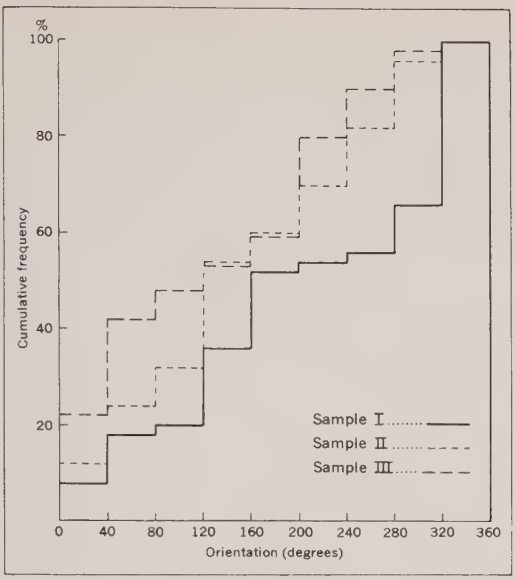

FIGURE 5. Cumulative-frequency histograms for samples with observations grouped into 40-degree class intervals.

possibility in which samples are cumulated and the maximum percentage difference between pairs is recorded (*see* Table 1).

Table 1
Kolomogorov-Smirnov test of differences in sample distribution

	maximum percentage difference (^{d}n)
Between I and II	30 (significant at the 95 per cent level)
Between I and III	32 (significant at the 99 per cent level)
Between II and III	16 (not significant)

The data are tested by the Kolomogorov-Smirnov statistic (Miller and Kahn, 1962); it is non-parametric and, as such, has considerable application in geomorphological studies. The results indicate that the original visual assessment of samples I, II and III (Figure 1) was correct in that samples I and III do not have the same sample-frequency distributions. It would appear, therefore, that the three samples cannot be combined to give a more precise estimate of the ice movement.

Although the above test provides useful information, it does not determine the preferred alignment of the samples, nor does it provide a comparison between the observed data and either a uniform or a random distribution. Quite clearly, before a preferred orientation can be interpreted it must be shown that the distribution of axial directions is non-random or isotropic. If further refinement is possible, the original data may be tested against theoretical models intended to characterize certain environmental conditions. The usefulness of this approach will be conditioned by the selection of realistic models.

The three samples were further analyzed by the two-dimensional vector analysis (Krumbein, 1939), by the chi-square test and by the three-dimensional vector method (Table 2).

The two-dimensional vector analysis

The two-dimensional vector analysis for the 180-degree distribution shown in Figure 1, gives a preferred orientation and a vector strength R. Dip is ignored and is thus not considered to be diagnostic. Vector strength may be tested against the null hypothesis of randomness. Table 2 indicates that the preferred pebble orientation of sample I is 347 degrees and the sample is thus non-random at the 99 per cent level. The fabric of sample II is apparently random while in sample III the preferred orientation is 43 degrees and the null hypothesis of randomness is rejected at the 95 per cent level. Such shifts in preferred orientations are surprising in view of the proximity of the sampling sites and the lack of textural and lithological change. The problem now is to determine whether or not these variations represent reasonable between-site fluctuations thus permitting all three samples to be combined to provide a better estimate of ice movement.

In two-dimensional fabrics a standard deviation is calculated around the resultant vector and the maximum F ratio (Hartley, 1950) derived by dividing s^2 max./s^2 min. where s^2 = variance, and entering the appropriate table. In the present case F max. (d.f. 3,98) is 2.28 and the hypothesis that the variances are homogeneous is rejected. These samples cannot, therefore, be combined. This suggests that the change in mean orientation is connected with a change in direction of the transport vector and that changes in orientation occur within the limited vertical section of about 3 metres. This must reflect shifts in the depositional environment which are not reflected in the stratigraphical units.

Table 2

Values for samples I, II and III for various statistical tests (N = 50)

	I	II	III
Two-dimensional vector analysis			
(1) *Chi-square* (180° range)	58.2***	4.73 NS	20.13**
(2) *Two-dimensional vector analysis* (180° range)			
orientation (degrees)	347		43
R	27.16**	8.55 NS	14.36*
Combined sample-orientation		352°	
R		25.62*	
(3) *Arithmetic mean* (minimum variance)	353°	326°	50°
standard deviation	31.0°	46.8°	41.8°
95 per cent confidence limits, standard error	±8.6°	±13.0°	±11.6°
Three-dimensional vector analysis			
(1) *0° reference plane*			
orientation	188°	01°	08°
dip	84°	47°	75°
R	21.7*	12.86*	19.11**
k	1.73	1.31	1.58
95 per cent confidence limits	±23.4°	±35.1°	±26.1°
(2) *30° reference plane*			
orientation (after re-rotation)	167°	141°	34°
dip (after re-rotation)	01°	30°	20°
R	37.25***	24.44**	33.8**
k	3.8	1.9	3.02
95 per cent confidence limits	±11.9°	±20.9°	±14.0°
(3) *90° reference plane*			
orientation (after re-rotation)	349°	208°	40°
dip (after re-rotation)	5°	10°	15°
R	40.4***	28.1**	34.6**
k	5.12	2.2	3.18
95 per cent confidence limits	±9.9°	±18.1°	±13.6°

*95 per cent significant level
**97 per cent significant level
***99 per cent significant level

Had the null hypothesis of homogeneity of variance been accepted, the next step would have been to ascertain whether the combined samples give identical resultant vectors in equation (3). In the case of the three samples under consideration there is no need to perform this test but, had it been necessary, it would have been calculated thus

$$F\ (\text{d.f. } 2,147) = \frac{147}{1} \cdot \frac{50.07-25.62}{99.93} = 36.015$$

The null hypothesis is rejected at the 99 per cent level.

The chi-square test

The chi-square value was calculated by grouping axial frequencies into 20-degree classes for a 180-degree distribution with degrees of freedom equal to 9-2. Thus samples I and III differ significantly from the hypothetical isotropic model but sample II does not (Table 2). This test, though easy to apply, gives no information on the preferred orientation of the pebbles and, as such, has limited value in studies concerned with delimiting regional and local ice movement. It is not, however, affected adversely by pronounced transverse maxima and thus provides an orientation-independent analysis of fabric strength (Andrews and Smithson, 1966).

THREE-DIMENSIONAL ANALYSIS

In theory we can postulate that pebbles will cluster about a mean direction and will have tendency to plunge up-glacier although some scatter may be expected around the declination and inclination of the transport vector. Thus we assume that the ideal distribution will be spherical-normal and that a point estimate will identify the sample. Table 2 gives the various parameters derived for the three samples under discussion. The first series of results indicates the distributions as normally presented, with directional sense controlled by the horizontal plane; the second series was derived after rotation of the reference plane through 30 degrees; the third involves a reference plane at 90

degrees to the horizontal with the observations clustering around the pole. The direction of rotation must be selected on some rational basis, related either to maximum cluster or to some determined direction. Table 2 illustrates the variation in parameters which now occur because of these manipulations. It should be noted that the approximation to a Fisherian distribution, i.e., spherical-normal, is considered insufficient if $k < 3$. The correct definition of the spherical radius of confidence is that the probability of the true direction deviating in direction more than $\phi°$ from the calculated resultant direction is 5 per cent (Steinmetz, 1962, p. 806).

Horizontal plane of reference (normal case)

The derived point for the mean vector is shown on Table 2. The values of R are such that the null hypothesis of randomness must be rejected. This contrasts with the results of the two-dimensional analysis and is explicable in terms of the smaller dispersion of dip amounts compared to the spread of orientation observations. The fallacy of this coordinate system for the rational analysis of till fabrics is indicated, however, by the position of the mean vector (Table 2) which has no physical meaning. The opposing modes have tended to cancel each other and as a result the distribution is balanced about the pole.

Reference plane rotated by 30 degrees

Table 2 indicates the considerable improvement in parameters R and k which results from this transformation. The values for R have increased 70 to 80 per cent compared to the horizontal case above and k, the estimate of precision, has increased to $\geq$ 3.0 in samples I and III. The direction and dip of the mean vector for samples I and III are physically feasible according to Figure 1 and provide good estimates of both mean orientation and mean dip as compared with the horizontal case. The 95 per cent confidence limits for samples I and III are greater for the three-dimensional analysis than for the standard arithmetic treatment. This value could be reduced by increasing the number of pebbles per sample although experience has shown that an increase in sample size does not reduce the standard deviation itself. Experiments have indicated that with a sample of 25 pebbles the standard deviation is the same as for 100 pebbles. The value of $k_{max.}/k_{min.}$ for samples I to III is 2.0; variance is, therefore, heterogeneous and the three samples may not be combined as they represent three vertically differentiated fabric populations.

Reference plane rotated by 90 degrees

With this rotation (Figure 2 and Table 2) the y and z axes are horizontal while the pole represents pebbles lying horizontally after rotation about the selected axis. This transformation (Table 2) provides the maximum R and k values and thus provides the best solution to the direction of the mean vector. The increases represent a slight improvement of between 4 and 15 per cent over a 30-degree rotation. The mean vectors for samples I and III have moved slightly (Table 2) but they are within the 95 per cent limit for the 30-degree rotation series. Sample I indicates an alignment of the pebble '*a*' axes toward 350 to 170 degrees with the dip being essentially horizontal. In contrast, sample III indicates movement from a bearing of 40 degrees, with pebbles having steeper dips (Figure 1). Sample II is not easy to interpret and although not strictly random, the best explanation is that it represents the zone of change between samples I and III and thus possesses no distinct pattern itself.

This last rotation is considered superior to the others and its use is recommended for till fabric analysis.

Problem of pebbles lying transverse

During the deposition and alignment of the pebbles within the till matrix, two distinct processes appear to operate: *first,* the process whereby material takes up an orientation and dip approximately parallel to movement within the till and possibly in the ice itself, details of position being determined by particle shape, texture and other variables; *second,* the rolling process whereby pebbles are turned so as to lie transverse to the direction of movement. Published work indicates that this latter process is rarely the dominant one. The direction of movement is indicated by pebbles in the *A*

lineation and so pebbles lying in the *B* lineation do not contribute any significant information to the analysis and may, therefore, be considered anomalous. This does not imply that they should be omitted from discussion, but it is stressed that their inclusion weakens the effectiveness of the analysis of the direction of ice movement. To permit comparisons, it is essential that sample numbers be kept constant, thus it is proposed that 10 per cent of the observations lying ± 90 degrees from the preferred orientation after a 90-degree rotation has been completed, be omitted from the calculations and the results rerun. Table 3 lists the results of such a procedure for samples I, II and III. Clearly all statistics increase in significance. The need for such an adjustment varies and in many cases no adjustment may be necessary. However, the amount and location of fabrics with pronounced transverse maxima are of some interest as they are not present in all samples or at all sites.

Manipulation of this sort is not in any sense to be construed as "fudging" the results. As illustrated in Figure 6 and Table 4, till fabrics showing parallel and transverse maxima are composed of two distinct sample distributions both in the two- and the three-dimensional cases. The problem here is to delimit the ranges of the two distributions. This may be done by individual inspection or may be accomplished by setting limits based on previous experience. Such limits may be ± 60 degrees about the preferred orientation for pebbles lying in the *A* lineation and ± 30 degrees for pebbles lying transverse (Figure 6). The numbers in each group will vary from sample to sample and transverse maxima may not be present in all instances. The ratio of the number of pebbles in each position *A*:*B* will provide interesting and probably diagnostic criteria for the separation of till sheets according to the physics of deposition.

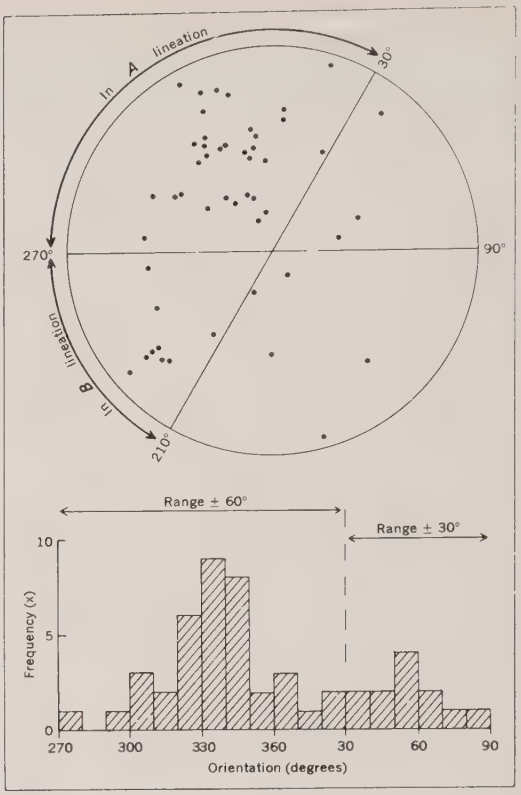

FIGURE 6. Histogram and polar equidistant projection of a till fabric possessing a pronounced secondary maximum.

Table 3

Three-dimensional vector analysis on samples I, II and III, omitting transverse readings, where N = *40 and a rotation through 90° has been made*

	I	II	III
Orientation	336	197	38
Dip	5	6	14
R	36.7***	26.5**	32.2***
k	11.7	2.9	5.0
95 per cent confidence limits	±6.9	±16.4	±11.3

**97 per cent significant level
***99 per cent significant level

Table 4

Three-dimensional vector results of observations in the A *and* B *lineations* (see *also Figure 5)*

Lineation	*R*	Orientation	Dip	*k*	95 per cent confidence limits	N
A	28.9	159°	1°	4.5	±13	41
B	8.3	236°	6°	11.5	±16	9
Entire fabric	33.4	297°	28°	3.0	±14	50

SUMMARY AND CONCLUSION

Till fabrics require and respond to detailed analysis. Various treatments have been discussed in this paper and applied for illustration to

three samples of 50 pebbles each from a location in northeastern England. Nearly all methods show that these samples, taken from lithologically similar till and within a 3-metre vertical section, may not be assigned to the same population. This suggests that a major change in fabric orientation and dispersion occurred within a limited vertical extent and with no stratigraphic trace. Kauranne (1960) noted a similar change in orientation within a limited vertical section in a detailed study of glacial tills in Finland and demonstrated that results from sites 10 to 100 metres apart may differ significantly. The processes of subglacial deposition are still not completely understood and it is suggested that previous explanations involving shear planes and ice/till contact may not always be correct. A more feasible process might be the flow of water-soaked basal till under pressure. Such a process could result in fabrics being aligned in response to a combination of slope control and ice movement. Sampling in a deep glaciated valley where ice movement is severely restricted in direction might be a promising field for further investigation.

The analysis of till fabric data by three-dimensional vector analysis has been discussed and the programs used for computation by IBM 1620 and Control Data 3100 are attached as an Appendix. Both programs are written in FORTRAN.

It is clear that one obstacle to correct interpretation of results is the use of conventional projections. It is suggested that in order to maximize the degree of fabric cluster, the treatment should be more flexible and should involve the use of a selected reference plane. Rotation through 30 degrees might be adequate for most samples although a rotation of 90 degrees is more suitable. Table 2 indicates that both degrees of rotation decrease the spherical radius of confidence by about one-half.

This paper is not primarily concerned with the mechanism of fabric origin, nevertheless, the shift in orientation between sample I and sample III is intriguing. We have implied that they both represent *A* lineations, but it may be equally important to note that the lower drab till is directly overlain by a reddish till (The Purple Till of northeast England) whose fabric corresponds in orientation to that of sample III. There is a possibility that the orientation and the characteristically low dips of sample I reflect a *B* lineation, i.e., one transverse to the ice movement. This might be caused by thrusting or folding of the lower till layers so that pebbles became reorientated by rolling.

Finally, the three-dimensional vector technique may be extended in application beyond the methods described here. It could be used to estimate the number of observations necessary to obtain a valid estimation of ice movement (Watson and Irving, 1957 and Steinmetz, 1964). Till fabrics, in common with cross-bedding, represent relatively dispersed fabrics with wide ranges in orientation. These fabrics may be compared to palaeomagnetic data for which the three-dimensional tests were originally devised and in which k values are high. This is illustrated by the small 95 per cent confidence figures which are usually less than $\pm$ 12 degrees for very small samples, whereas the majority of till fabrics lie in the range $\pm$ 10 to $\pm$ 20 degrees with a sample size of $N = 50$.

Till fabrics are assumed to have point maxima and it is thus postulated that they may be described by a spherical-normal distribution with a rather low precision parameter. However, in some samples there is a large number of transverse pebbles which decreases the precision parameter to < 3.

Finally we may sum up the advantages and disadvantages of the three-dimensional vector analysis as opposed to either graphical solutions or to two-dimensional studies.

Advantages

(1) the rapid processing of results which permits analysis of data during field work and provides guidelines for the research project while it is still in the observational stages.
(2) the providing of parameters useful in comparative studies on differing glacial or glacio-fluvial deposits.
(3) the testing of data against a physical rational model.
(4) the using of output information to determine the number of fabrics per exposure and/or the number of pebbles per site for any given degree of accuracy.

(5) the utilization of data on both orientation and dip.

Disadvantages

(1) the uniqueness of each individual fabric is lost if not plotted.
(2) the value of R may not necessarily measure the dispersion around the mean orientation and dip.
(3) the derived value for dip is *not* the mean dip though in a spherical-unimodal-distribution, it closely approximates it.
(4) the advantage of rapid processing may be lost in till fabric analysis because of bimodal distributions and this will have to be rectified by the lengthy process of rotating the points.

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Appendix

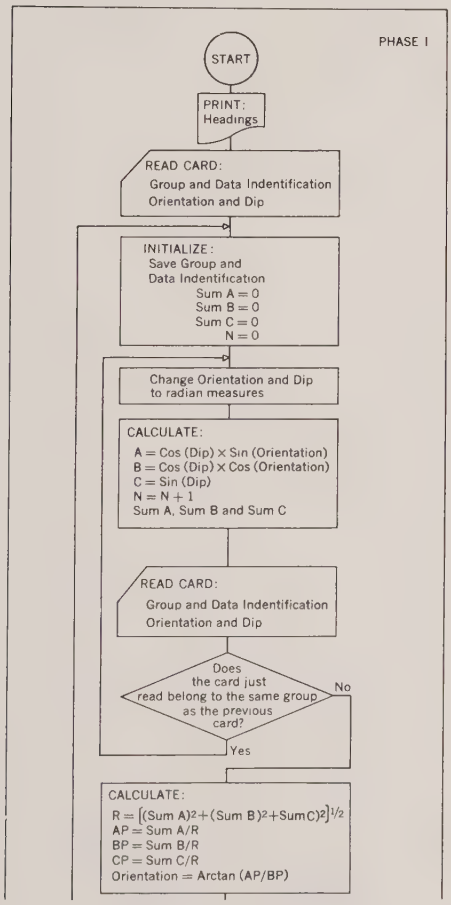
In developing the FORTRAN program for till analysis, sixteen columns of a standard punch card were used to record information on sample number, pebble number within the sample, proximal or distal site (for moraine studies), orientation from 0 to 359 degrees, and dip from 0 to 90 degrees. As illustrated in the sample card below, column 9 must be filled with 1 or 0 even if there is no information pertaining to location.

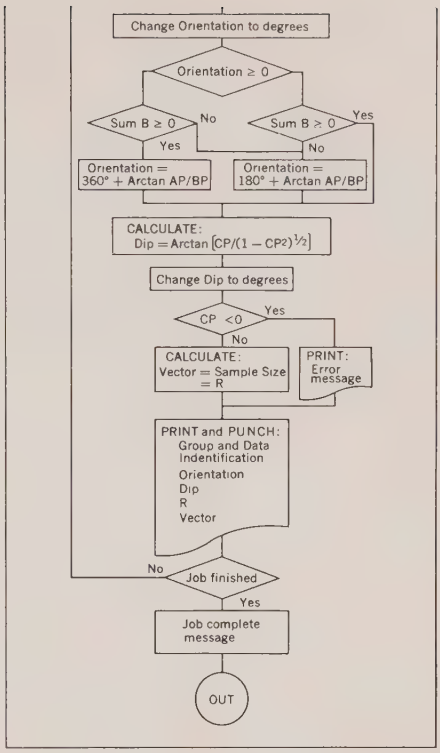
Input for the till fabric program

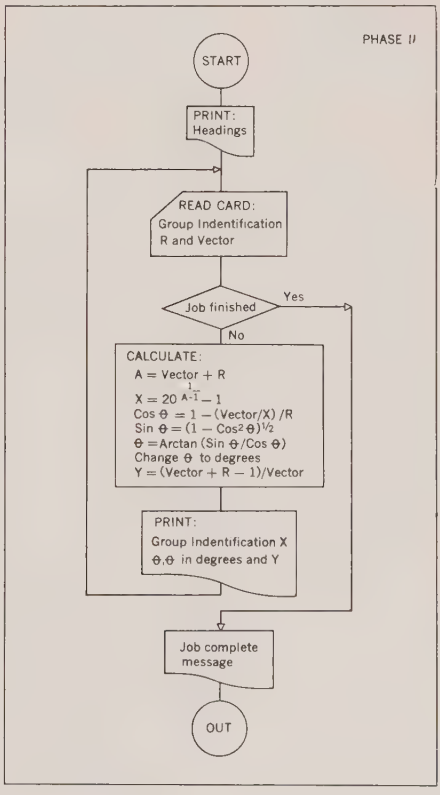
Sample No.				No. obs.					(Orientation)				(Dip)	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	9	1		0	0	1		0		1	4	5		2	4
0	9	1		0	0	2		0		1	3	0		1	1
0	9	1		0	0	3		0		0	9	3		1	6
.	.	.		.	.	.		.		.	.	.		.	.

On the basis of the information thus recorded the following flow pattern and two-phase FORTRAN program were developed for the IBM 1620. This was later revised and converted into a single-phase FORTRAN program for the CDC 3100.

Flow Pattern


PHASE I
START
PRINT: Headings
READ CARD: Group and Data Indentification Orientation and Dip
INITIALIZE: Save Group and Data Indentification Sum A = 0 Sum B = 0 Sum C = 0 N = 0
Change Orientation and Dip to radian measures
CALCULATE: A = Cos (Dip) × Sin (Orientation) B = Cos (Dip) × Cos (Orientation) C = Sin (Dip) N = N + 1 Sum A, Sum B and Sum C
READ CARD: Group and Data Indentification Orientation and Dip
Does the card just read belong to the same group as the previous card?
No
Yes
CALCULATE: R = [(Sum A)² + (Sum B)² + Sum C)²]^1/2 AP = Sum A/R BP = Sum B/R CP = Sum C/R Orientation = Arctan (AP/BP)




PHASE II
START
PRINT: Headings
READ CARD: Group Indentification R and Vector
Job finished
Yes
No
CALCULATE: A = Vector + R X = 20^(A^-1) − 1 Cos θ = 1 − (Vector/X) /R Sin θ = (1 − Cos² θ)^1/2 θ = Arctan (Sin θ/Cos θ) Change θ to degrees Y = (Vector + R − 1)/Vector
PRINT: Group Indentification X θ, θ in degrees and Y
Job complete message
OUT

```
      FORTRAN PROGRAM FOR THE IBM 1620
      PRINT 500
500   FORMAT (6H1IDENT,2X,14HNATURE OF DATA,3X,11HORIENTATION,2X,3HDIP,
     16X,1HR,5X,6HVECTOR)
      PRINT 501
501   FORMAT (1H0,10X,12H0 = PROXIMAL)
      PRINT 502
502   FORMAT (1H0,10X,11H1 = DISTAL  )
      PRINT 503
503   FORMAT (59H -----------------------------------------------------
     1---)
      PRINT 504
504   FORMAT (///)
      DO 801 I=1,50
      READ 100,ID,ND,ORT,DIP
100   FORMAT (I3,4X,I2,F4.0,F3.0)
  7   IDR=ID
      NDR=ND
      SUMA=0.
      SUMB=0.
      SUMC=0.
      N=0
  1   DIP=DIP*.017453292
      ORT=ORT*.017453292
      B=COSF(DIP)*COSF(ORT)
      *A=COSF(DIP)*SINF(ORT)
      C=SINF(DIP)
      N=N+1
901   SUMA=SUMA+A
      SUMB=SUMB+B
      SUMC=SUMC+C
      READ100,ID,ND,ORT,DIP
      IF(ID-IDR)2,1,2
  2   R=SUMA*SUMA+SUMB*SUMB+SUMC*SUMC
      R=SQRTF(R)
      RI=1./R
      AP=SUMA*RI
      BP=SUMB*RI
      CP=SUMC*RI
      ORTN=ATANF(AP/BP)
      IORTN=ORTN*57.29578+.5
      IF(ORTN)3,5,5
  5   IF(BP)13,4,4
  3   IF(BP)13,12,12
 12   ORTN=360+IORTN
      GO TO 4
 13   IORTN=180+IORTN
  4   ASIN=ATANF(CP/SQRTF(1.-CP*CP))
      IASIN=180.*ASIN/3.1415826+0.5
      IF(CP)8,6,6
  8   PRINT 300,IDR
300   FORMAT(14H DIP IN SAMPLE,I6,10H NEGATIVE )
  6   VEC=N
      VEC=VEC-R
      PUNCH 102,IDR,ND,IORTN,IASIN,R,VEC
      PRINT 102,IDR,ND,IORTN,IASIN,R,VEC
102   FORMAT(I5,9X,I2,12X,I4,6X,I3,1X,2F8.2)
      IF(ID)7,1000,7
801   CONTINUE
1000  PRINT 200
200   FORMAT(20H PROCESSING COMPLETE)
      CALL EXIT
      END
C     TILL FABRIC ANALYSIS      -PHASE II
      PRINT 500
      PRINT 501
      PRINT 503
      PRINT 502
502   FORMAT(1H )
  1   READ 5,IDENT,R,VECTOR
      IF(IDENT)10,100,10
 10   A=R+VECTOR
      X=((20.**(1./A-1.)))-1.
      CTHETA=1.-(((A-R)*(X))/R)
      STHETA=1.-CTHETA**2
      STHETA=SQRTF(STHETA)
      THETA=ATANF(STHETA/CTHETA)
      CDEG=THETA/0.017453
      Y=(A-1.)/(A-R)
      PRINT 600,IDENT,X,THETA,CDEG,Y
      GO TO 1
100   PRINT 101
      CALL EXIT
  5   FORMAT(I5,37X,2F8.2)
101   FORMAT(11H END OF JOB)
500   FORMAT(39X,9H THETA IN,15X,12H ESTIMATE OF)
501   FORMAT(5X,6H IDENT,8X,2H X,11X,8H RADIANS,10X,8H DEGREES,
     116X,10H PRECISION)
503   FORMAT(5X,6H -----,7X,4H ---,10X,26H --------------------------,
     16X,11H ----------)
600   FORMAT(I10,2X,4E16.8)
      END
```

```
FORTRAN PROGRAM FOR THE CDC 3100
      PROGRAM F20401
C
C     TILL FABRIC ANALYSIS
C     GEOGRAPHICAL BRANCH
C
      DIMENSION IDRE(50)
      NPAGE=1
      INDEX=0
      READ(60,100) ID,ND,ORT,DIP
    7 IDR=ID
      NDR=ND
      SUMA=0.
      SUMB=0.
      SUMC=0.
      LINE=0
      N=0
      GO TO 651
    1 DIP=DIP*.017453292
      ORT=ORT*.017453292
      COSD=COS(DIP)
      A=COSD*SIN(ORT)
      B=COSD*COS(ORT)
      C=SINF(DIP)
      N=N+1
      SUMA=SUMA+A
      SUMB=SUMB+B
      SUMC=SUMC+C
      READ(60,100) ID,ND,ORT,DIP
      IF(ID-IDR)2,651,2
    2 R=SUMA*SUMA+SUMB*SUMB+SUMC*SUMC
      R=SQRTF(R)
      ORTN=ATAN(SUMA/SUMB)*57.29577951
      IORTN=ORTN
      IF(SUMB) 13,5,5
    5 IF(ORTN) 12,50,50
   12 IORTN=360+IORTN
      GO TO 50
   13 IORTN=180+IORTN
   50 CP=SUMC/R
      PTBAL=ATAN(CP/SQRT(1.-CP**2))*57.29577951
      IPTBAL=PTBAL
      IF(SUMC) 8,6,6
    6 A=N
      X=20**(1./(A-1.))-1.
      COSTHTA=1.-(A-R)*X/R
      SINTHTA=SQRT(1.-COSTHTA**2)
      THETA=ATAN(SINTHTA/COSTHTA)
      CDEG=THETA*57.29577951
      Y=(A-1.)/(A-R)
      WRITE(61,602)
      WRITE(61,610) NPAGE
      NPAGE=NPAGE+1
      DO 3 INDEXDO=1,5
    3 WRITE(61,603)
      WRITE(61,604) IDR
      WRITE(61,605) NDR
      WRITE(61,606) IORTN
      WRITE(61,607) IPTBAL
      WRITE(61,608) R
      WRITE(61,609) CDEG
      WRITE(61,615) Y
      IF(ID) 7,1001
 1001 WRITE(61,602)
      IF(INDEX) 1002,1000
 1002 WRITE(61,601)
      WRITE(61,603)
      INDEX=INDEX-1
      DO 1003 I=1,INDEX
 1003 WRITE(61,614) IDRE(I)
      WRITE(61,603)
 1000 WRITE(61,200)
      STOP
    8 INDEX=INDEX+1
      IDRE(INDEX)=IDR
      GO TO 6
C
C     SUBROUTINE PRINT
C     TILL FABRIC ANALYSIS
C
  651 IF(LINE) 800,652
  652 WRITE(61,602)
      WRITE(61,610) NPAGE
      NPAGE=NPAGE+1
      WRITE(61,603)
      WRITE(61,611)
      WRITE(61,612)
      WRITE(61,603)
  800 WRITE(61,614) IDR,NDR,ORT,DIP
      LINE=LINE+1
      IF(LINE.GT.45) 701,  1
  701 LINE=0
      GO TO  1
C
C     END OF SUBROUTINE
C
  100 FORMAT(I3, 4X, I2, F4.0, F3.0)
  601 FORMAT(34H DIP IN FOLLOWING SAMPLES NEGATIVE)
  602 FORMAT(1H1)
  603 FORMAT(///)
  604 FORMAT(16X,15H IDENTIFICATION,12X,I5)
  605 FORMAT(16X,15H NATURE OF DATA,12X,I5)
  606 FORMAT(16X,15H ORIENTATION     ,12X,I5)
  607 FORMAT(16X,17H POINT OF BALANCE,10X,I5)
  608 FORMAT(16X,2H R,20X,E10.4)
  609 FORMAT(16X,2H C,20X,E10.4)
  610 FORMAT(48X,9H PAGE NO.,I5)
  611 FORMAT(13X,9H  IDENT.,7H NATURE,3X,7H ORIEN-,6H  DIP)
  612    FORMAT(22X,8H OF DATA,3X,7H TATION)
  614 FORMAT(13X,I7,I6,F12.0,F7.0)
  615 FORMAT(16X,2H Y,20X,E10.4)
  200 FORMAT(20H PROCESSING COMPLETE)
      END
```

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THE MIXING OF THE WATERS OF THE LIARD AND GREAT BEAR RIVERS WITH THOSE OF THE MACKENZIE

J. Ross Mackay

ABSTRACT

The interpretation of temperature and Secchi disk transparency readings for the right and left banks of the Mackenzie River below its junction with the Liard at Fort Simpson, N.W.T. are discussed. The measurements, made in 1963 and 1964, were taken in June after break-up. In both years the results show that, 200 miles downstream, the warmer and more turbid waters of the Liard had not fully mixed with those of the Mackenzie. Similarly, a study of the Great Bear River below Fort Norman, N.W.T. shows that the mixing of its waters with those of the Mackenzie was not fully completed 50 miles below their confluence.

RÉSUMÉ

L'auteur analyse les observations faites sur la température de l'eau ainsi que celles de sa transparence obtenues au moyen de disque Secchi, sur les rives droite et gauche du fleuve Mackenzie en aval du confluent de la rivière Liard à Fort Simpson (T. N.-O.). Les observations ont été effectuées après la débâcle en 1963 et en 1964 au cours du mois de juin. Les résultats, pour ces deux années, montrent qu'à 200 milles en aval, les eaux plus chaudes et plus troubles de la Liard ne sont pas encore complètement mélangées à celles du Mackenzie. De même, une étude de la Grande rivière de l'Ours en aval de Fort Norman (T. N.-O.) montre que ses eaux ne sont pas encore complètement mélangées à celles du Mackenzie à 50 milles en aval de leur confluence.

The waters of the Mackenzie River originate in Great Slave Lake which is large, deep, frigid and relatively free of sediment. No sizeable rivers join the Mackenzie between its outlet (Mile 0) and Fort Simpson (Mile 208). At this latter point, however, its largest tributary, the Liard, enters on the left bank at an angle of 50 degrees, its surface waters generally sweeping well beyond mid-stream toward the right bank of the main river. Between Fort Simpson and Point Separation (Mile 912) many left and right bank rivers flow in, a major one being the Great Bear River which drains from Great Bear Lake to enter on the right bank of the Mackenzie at Fort Norman (Mile 512) (Figure 1).

Break-up of ice on the Mackenzie River system occurs between early May and early June, the Liard opening earlier and the Great Bear River usually later than the Mackenzie itself. The waters of the Liard are warm and silty in May and June, a marked contrast to the clearer, colder waters of the Mackenzie. The two streams flow together unmixed for miles with the line of demarcation between them being clearly defined, especially when seen from the air. Kindle (1918) was able to observe a difference between the waters of the two rivers for 160 miles downstream to beyond Wrigley (Mile 359), and observations made in June 1963 and June 1964 showed that the Liard and Mackenzie waters had not completely mixed 200 miles downstream from their confluence.

In contrast to the Liard, the waters of the Great Bear River at Fort Norman resemble those of the Mackenzie at Fort Simpson in temperature and transparency. This is not unnatural as each river at its outlet has just emerged from a large, deep, cold lake. By the

MS submitted November, 1965.

FIGURE 1. The Mackenzie River valley.

time the Mackenzie has reached Fort Norman it has become warm and turbid and the Great Bear River is, therefore, much colder and clearer. The two streams may not fully mix for about 50 miles. Kindle (1918, p. 345) suggested that the clear waters of the Great Bear River probably occupied the eastern half of the main stream as far as the head of the delta at Mile 917, but neither in June 1963 nor June 1964 could indisputable evidence of Great Bear River water be detected beyond Norman Wells (Mile 562). There was no difficulty in June 1963 in distinguishing between Mackenzie and Great Bear waters within about 46 metres (150 ft) of the right bank as far as Mile 550 (Figures 2 and 3), and slight differences were evident up to about Mile 570. Compared to the Mackenzie, however, the Great Bear River discharge is too small to be of importance very far downstream.

Examples of such long distance flow of unmixed river waters are extremely rare and references in the literature are therefore limited.

It is the purpose of this paper to discuss some temperature and transparency measurements of Liard, Great Bear and Mackenzie waters in relation to their rate of mixing.

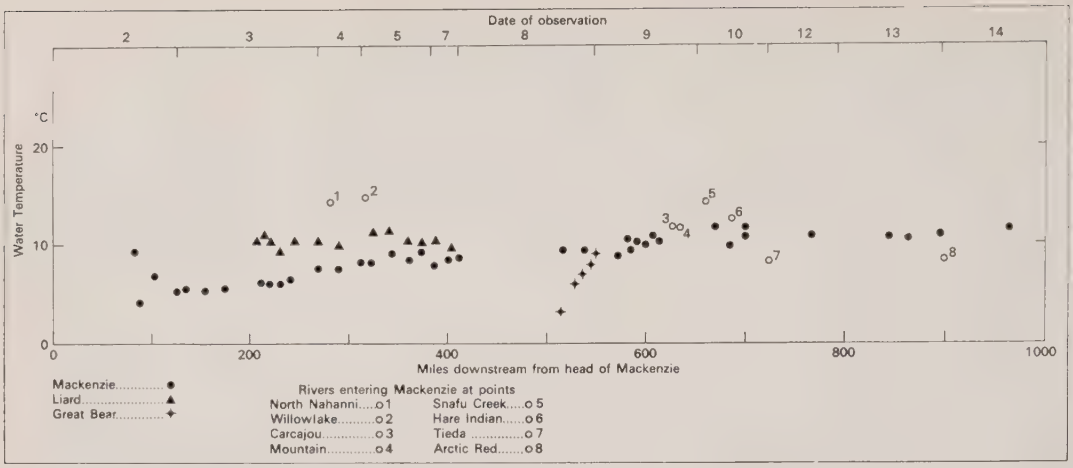

FIGURE 2. Temperature observations, June 1963.

Among other useful purposes served, such a study may be of value in evaluating the pattern of waste disposal downstream from river settlements.

The present work is based principally upon measurements taken during early June in 1963 and 1964 on the voyage by freight canoe from Fort Providence to the arctic coast. Temperatures were measured with a thermistor probe to 0.1°C at a depth of approximately 1 metre. The water transparency was estimated by averaging the depths of disappearance and reappearance of a white Secchi disk roughly 30 cm in diameter. Transparency was recorded in centimetres.

THE WATERS OF THE MACKENZIE AND THE LIARD RIVERS

The incomplete records existing for the period 1938 to 1964 indicate that the combined discharge from the Mackenzie and Liard rivers at Fort Simpson in June ranged from approximately 350,000 cu ft/sec to about 700,000 cu

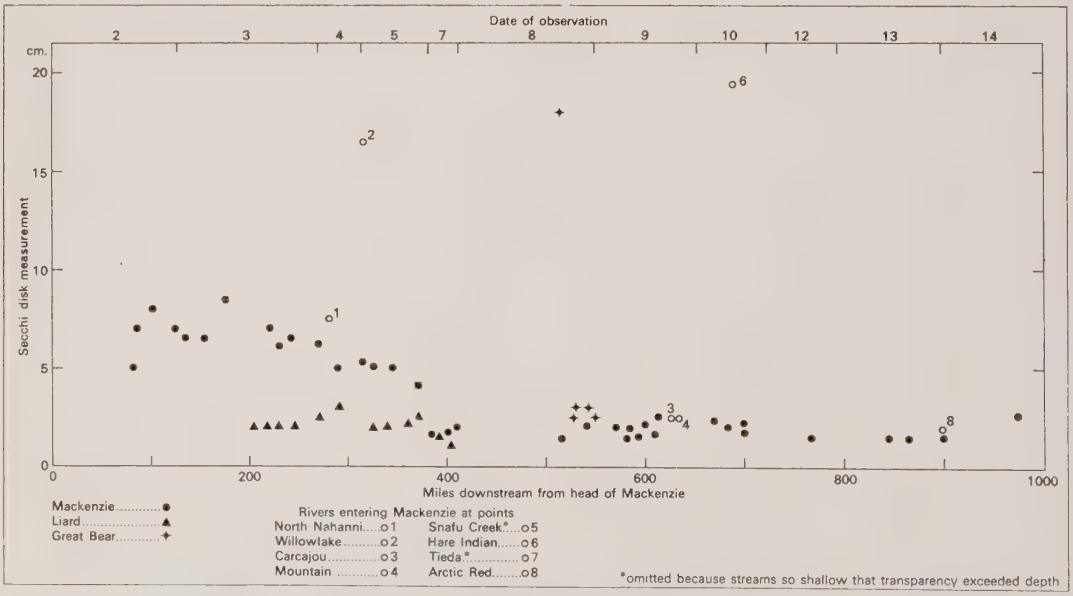

FIGURE 3. Transparency observations, June 1963.

ft/sec. Data for early June 1963 and for all of June 1964 are missing, but available records suggest that the June discharge in both years was probably above average. The volume of water discharged by the Liard is not accurately known but it has been estimated that in early June at Fort Simpson it may nearly equal that of the Mackenzie itself.

In order to identify the Liard and Mackenzie waters in 1963 and 1964, temperature and Secchi disk readings were taken above their confluence as well as downstream. After some experimentation in taking surface and subsurface temperature measurements and Secchi disk readings at close intervals across the river, it was found that surface measurements about one-quarter of the river's width from each bank gave consistent results. Measurements close inshore proved erratic because of shallow water effects and the discharge of tributary streams. As long as temperature and transparency contrasts persisted, the right and left bank readings have been assumed to reflect either predominantly Mackenzie or predominantly Liard water and have been so referred to in this paper.

Temperature and transparency data for early June 1963 are plotted in Figures 2 and 3. On June 2, 1963, the Liard water spread across two-thirds of the width of the Mackenzie at, and immediately downstream from, Fort Simpson. Some overrunning of Mackenzie water by Liard water is inferred. The density difference between water at 10.5°C (Liard) and water at 6.0°C (Mackenzie) as measured at Fort Simpson would be about 300 parts per million. To what extent this might have been offset by impurities is unknown for the sediment load is highly variable (Mackay, 1963, pp. 99-100; Thomas, 1957 and 1961). Field evidence in early June 1963 and 1964, however, seemed to indicate considerable overrunning.

In the course of the 200 miles between Fort Simpson and Mile 410, the temperature of the Mackenzie waters rose from 6°C to 9°C while that of the Liard dropped from 10.5°C to 9.5°C. On June 6-7, 1963, there was heavy rain (0.70 inches at Wrigley) accompanied by strong winds. So much turbid water was flushed into the river by swollen tributaries and stirred up by waves along the muddy banks, that attempts to take meaningful right and left bank readings were futile. This disturbance is clearly seen in Figure 3 where a sudden drop in the transparency of both the Mackenzie and the Liard is recorded on June 7. Had this stormy weather not occurred, the temperature and transparency differences could probably have been detected as far as Mile 450 if not farther.

As in 1963, measurements taken in 1964 (Appendix, Table 1) showed a similar tendency for the temperature and transparency of the two streams to approach each other somewhere about Mile 410. The temperatures of both the Liard and the Mackenzie at and below Fort Simpson were higher in early June 1964 than at the same time the previous year. In 1960, through the co-operation of the Royal Canadian Mounted Police, temperatures of Liard and Mackenzie waters were taken at Fort Simpson and of Great Bear and Mackenzie waters at Fort Norman. Water samples were also collected for turbidity measurements (Thomas, 1961). The contrast between Liard and Mackenzie waters in early June 1960 appears to have been similar to that at the same period in 1963 and 1964. The 1960 observations of both streams at Fort Simpson (Appendix, Table 2) show that it is not only in spring that the Liard is more turbid than the Mackenzie, but that this condition persists throughout the entire summer. Temperature changes of the two streams during the summer of 1960 are also shown in the Appendix, Table 2.

Discussion of factors which influence mixing

Interpretation of the measurements of temperature and transparency/turbidity is difficult, because of the almost complete absence of hydrologic data. Some of the factors which should be considered are: (1) discharge and stage; (2) influence of tributaries; (3) flow travel time; (4) weather; (5) bottom sediment temperatures; (6) channel form.

The following discussion centres on the 200-mile stretch downstream from Fort Simpson for early June 1963 and 1964.

*Discharge:** If it is assumed that the *only* change in water temperature downstream from Fort Simpson is from the mixing of Mackenzie and Liard water, then the resulting temperature (T_r) after mixing would be

**Stage* has not been included in this discussion.

$$T_r = \frac{Q_m T_m + Q_l T_l}{Q_m + Q_l}$$

where T_r = resultant temperature if water is fully mixed at any river section

Q_m = discharge of the Mackenzie at Fort Simpson

Q_l = discharge of the Liard at Fort Simpson

T_m = temperature in °C of the Mackenzie at Fort Simpson

T_l = temperature in °C of the Liard at Fort Simpson

Also relevant to the final form of the equation:

T_a = temperature change due to advection from tributary streams

T_e = temperature increase/decrease because of heat exchange with atmosphere

T_b = temperature change resulting from heat exchange with bottom sediments

Any substitution from projected trends (Figure 2) or interpolation for intermediate values will give a ratio of Mackenzie to Liard discharge of about 0.5 ± 0.1, that is, the Mackenzie discharge as roughly half that of the Liard. From available hydrologic evidence this value is probably too low.

Influence of tributaries

Over the 200-mile stretch downstream from Fort Simpson, the influence of tributaries was to raise the temperature and transparency of both Liard and Mackenzie waters except after a heavy rain. In 1963, the temperature of the North Nahanni River, a left bank tributary (Figure 4), was 14.3°C at its mouth, and its warming effect was observed along the left bank for at least 10 miles downstream (Figure 2). A right bank tributary, the Willowlake River, with a temperature of 14.9°C at its

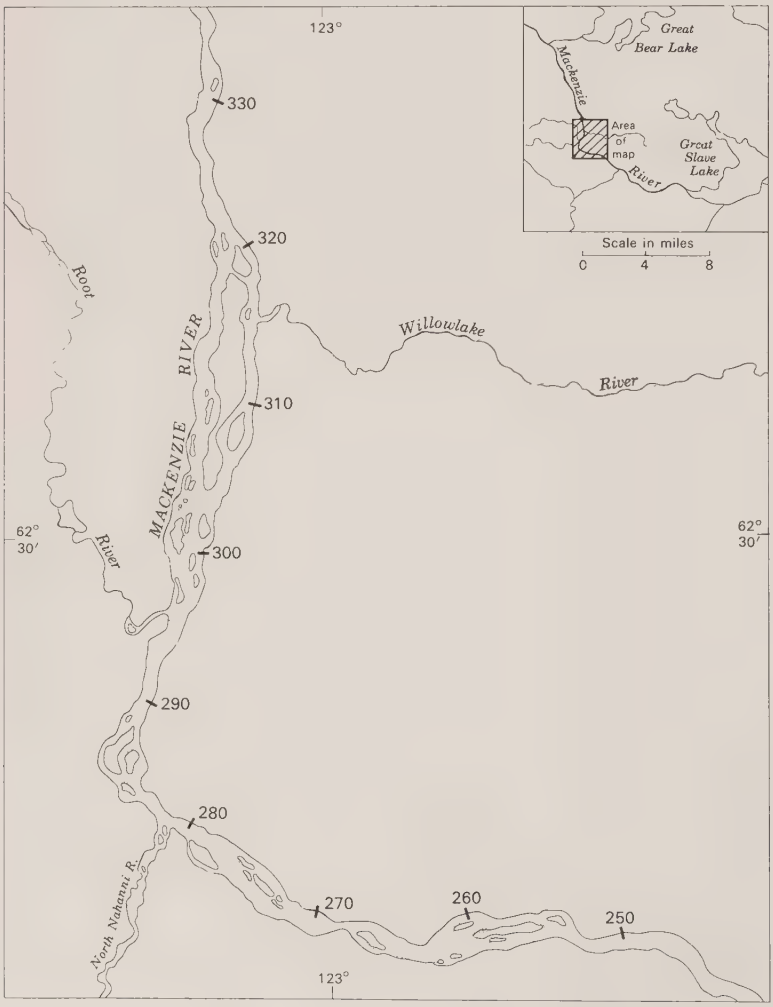

FIGURE 4
The island-studded reach of the Mackenzie River, between Mile 257 and Mile 322.

mouth, was not only nearly 7°C warmer than the Mackenzie but also very much clearer (Figures 2 and 3). The temperatures of the North Nahanni and Willowlake rivers at their mouths were about 6.5°C higher than the Mackenzie River at that point, in contrast to the Liard which in the same locality was only 2.5° warmer than the Mackenzie. Consequently, the warming effect of the North Nahanni and Willowlake waters was four or five times greater than that of an equal volume of Liard water. Nevertheless, as the contrasts in temperature between the Liard and Mackenzie waters were easily followed beyond the mouths of both the smaller tributaries, the advective effects (T_a) of these latter rivers were subordinate to the Liard-Mackenzie mixing process. The advective term, T_a, cannot be computed at present as discharge data for the North Nahanni or Willowlake rivers are not available. As shown in Figures 2 and 3, the effect of certain other downstream tributaries also appears to have been negligible in the over-all mixing process.

Flow travel time

The flow travel time of the water from Fort Simpson to Mile 410 probably averages over two days (Mackay, 1963). The 1963 and 1964 observations, therefore, would not be made on the same "parcel" of moving water over the 200-mile distance. However, if the periods 3 to 5 June 1963 (Figure 2) and 4 to 6 June 1964 (Appendix, Table 1) are considered, only a small linear "stretch" of moving water could have been involved.

Weather

Weather affected water temperatures during the several day flow period from Fort Simpson to Mile 410. Observation periods during 1963 and 1964 occurred during sunny, warm, dry days. Using weather data for Fort Simpson and Wrigley, a daily energy budget can roughly be computed by well-known methods. The estimated daily gain was about 400 ± 100 gm cal/cm^2/day. If the mean river depth is taken as about 8 metres (25 ft) the gain was possibly 0.5°C per day or about 1.0°C from Fort Simpson to Mile 410. Ranges of values can, of course, be given for other depths and other flow travel times. A temperature rise of 1°C seems quite reseasonable in view of river temperatures obtained for 1961 (Mackay, 1963a, p. 109) and of unpublished records for 1960, 1962, 1963 and 1964. If the change in water temperatures (T_e) from heat exchange with the atmosphere is assumed to be the same for both Liard and the Mackenzie waters, then the equation for the modified resultant temperature (T_r) already discussed becomes:

$$T_r = \frac{Q_m T_m + Q_l T_l}{Q_m + Q_l} + T_e$$

A substitution of values from Figure 2 with $T_e = 1$, makes the discharge of the Liard and Mackenzie rivers nearly equal and thus in agreement with inferred discharge data.

Bottom sediment temperatures

The mean annual river temperature for the combined Liard-Mackenzie flow below Fort Simpson is estimated at about 5.5°C ± 1°C. This estimate is based upon the recorded water temperatures for the summer of 1960 (Appendix, Table 2) and the fact that winter temperatures will be close to 0°C. The temperature of the subjacent bottom deposits will then fluctuate around the mean—with, of course, a lag. During May and June water temperatures increase rapidly so at that time there will be a heat loss to the colder bottom sediments. However, any substitution of values commensurate with inferred soil conductivities and temperature gradients suggests a downward heat loss of no more than a few gm cal/cm^2/day. This value is so small in comparison to the other terms that bottom effects (T_b) can be ignored.

Channel form

Very little is known about the channel geometry downstream from Fort Simpson. From Mile 208 to Mile 257 the river flows in a relatively straight course and is about a mile wide. The main current swings from bank to bank and the channel is interspersed with shoals and low islands. Between Mile 257 and Mile 322 (Figure 4), the river broadens to a maximum bank-to-bank width of 4 miles and divides and reunites around a continuous succession of shoals and islands. This would seem to provide ideal conditions for mixing the waters, but such was not the observed result. From Mile 322 to Mile 410 the channel is for the most part straight, narrow and free of islands, and it

might justifiably have been expected that the concentration of water into a narrow channel after it had flowed through an island-studded reach, would be all that was needed to complete the mixing process. Yet, there is no doubt that in 1963 and 1964, the mixing of the Liard and Mackenzie waters was still incomplete at a distance of 200 miles from their confluence.

THE WATERS OF THE MACKENZIE AND GREAT BEAR RIVERS

Observations relative to the mixing of Great Bear River waters with those of the Mackenzie have been considered in the same way as those of the Liard. Temperature and transparency data for 1963 are plotted in Figures 2 and 3. The 1960 temperature data referred to in connection with the transfer of heat to bottom sediments, as well as the turbidity records for that year, are contained in the Appendix, Table 3.

SUMMARY AND CONCLUSION

The temperature and transparency differences between Liard and Mackenzie water were easily detected 200 miles downstream from their confluence at Fort Simpson in the summers of 1963 and 1964. Under favourable climatic conditions and with accurate measurements, the contrasts could probably be detected for more than 250 miles downriver. As the average channel width is about a mile, the ratio of mixing length to channel width exceeds 200. The greatest mixing length probably obtains shortly after break-up when water contrasts are the greatest. Great Bear water can be distinguished at least 50 miles downstream.

In so far as present information permits conclusions, the observed changes in the temperature of the Mackenzie below its confluence with the Liard appears to depend mainly upon the initial temperatures of the two rivers and the warming or cooling which results from their mixing and from heat exchange with the atmosphere. Advection from tributary streams is certainly important but impossible to estimate at present because of the lack of discharge data. Changes arising from heat exchange with bottom sediments are believed to be relatively minor. In contrast to the Liard, the Great Bear waters are colder than those of the Mackenzie but the above conclusions would still hold.

ACKNOWLEDGMENTS

The writer thanks Dr. J. K. Stager for field help in 1963, and D. E. Kerfoot and D. K. MacKay for similar assistance in 1964. The Royal Canadian Mounted Police took the water temperatures at Fort Simpson and Fort Norman in 1960. Research support came from the Geographical Branch, Department of Mines and Technical Surveys; the Department of Northern Affairs and National Resources; the National Research Council; the University of British Columbia.

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1963a: Progress of break-up and freeze-up along the Mackenzie River. *Geog. Bull.*, no. 19, 103-116.

Thomas, J. F. J.
1957 : Industrial water resources of Canada. Mackenzie and Yukon River drainage basins in Canada, 1952-53. Mines Br., Ottawa, Water Survey Rept. no. 8, 78 p.
1961 : Chemical quality of the Mackenzie River and some of its tributaries. Mines Br., Mineral Processing Div., Ottawa, Test Rept. MPT 61-56, manuscript, 15 p.

Appendix

Table 1

Liard and Mackenzie water temperature and transparency readings, June 1964

Mile	Date (1964)	Liard temp. (°C)	Mackenzie temp. (°C)	Liard transparency (cm)	Mackenzie transparency (cm)
209	June 3	10.6		15	
215	3		9.0		75
217	4	10.6		15	
221	4		8.8		80
257	4		9.3		75
295	5		9.4		35
339	5	11.4		7	
363	6		10.9		30
365	6	11.5		7	
381	6		10.9		20
381	6	11.5		7	
399	7		11.1		12
399	7	11.9		7	

Table 2

Liard and Mackenzie water temperature and turbidity readings, at Fort Simpson, summer 1960

Date (1960)	Liard temp. (°C)	Mackenzie temp. (°C)	Liard (turbidity units)	Mackenzie (turbidity units)
April 29	(movement of ice)	(frozen)		
May 9	(open)	(movement of ice)		
24	7.2	4.4	220	15
28	10.0	4.4		
June 3	10.0	7.8		
7	12.2	7.8	300	5
16	13.3	8.9		
21	12.2	10.0	500	3
28	14.4	14.4		
July 5	15.0	14.4	300	3
13	14.4	13.3		
27	16.7	14.4	35	3
Aug. 3	18.9	15.6		
10	17.8	18.9	30	2
26	13.3	12.8	45	0.8
Sept. 1	12.2	12.2		
8	10.0	11.1	600	2
29	8.9	10.0	10	3
Oct. 10	(first ice)	(open)		
12	3.3	4.4	7	4
Nov. 25	(freeze-up)			

Table 3

Great Bear and Mackenzie water temperature and turbidity readings at Fort Norman, summer 1960

Date (1960)	Great Bear temp. (°C)	Mackenzie temp. (°C)	Great Bear (turbidity units)	Mackenzie (turbidity units)
May 11	(frozen)	(break-up)		
25	(break-up)	(river open)		
June 8	3.3	8.9	0.9	60
15	5.6	10.0		
22	4.4	13.3	1	45
29	7.2	14.4		
July 6	4.4	10.0	2	250
13	8.9	14.4		
20	8.9	14.4	0.8	30
27	8.9	14.4		
Aug. 3	11.1	17.8	0	25
Sept. 21	4.4	7.2	2	15
Nov. 14	(river open)	(freeze-up)		
16	(freeze-up)	(frozen)		

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PATTERN OF COASTAL UPLIFT AND DEGLACIERIZATION WEST BAFFIN ISLAND, N.W.T.*

J. T. Andrews

ABSTRACT

The marine limit in the Grant-Suttie Bay/Isortoq Fiord area is a major strandline formed in association with the Isortoq Phase moraines and established, according to radiocarbon dating, less than 7,000 years ago. Subsequent offshore updoming resulted in an upward tilt of the area toward S 35° W at the rate of 1.0 metre/km. A lower strandline at about 20 metres above sea level was formed less than 4,000 years ago. Uplift of the west coast of Baffin Island has been slow compared to adjacent glacial dispersal zones. It is suggested that this relates in part to the dampening effect of the Baffin Island ice cap which was of major proportions during the initial rebound period. Rates of uplift are compared from both sides of Foxe Basin and found to differ.

RÉSUMÉ

La limite marine de la région de la baie Grant-Suttie et du fjord Isortoq est une importante ligne de rivage formée par association aux moraines de la phase Isortoq et qui remonterait, selon la radiodatation au carbone, à moins de 7,000 ans. Des soulèvements en dôme au large ont eu pour résultat de soulever la région en l'inclinant vers le sud 35° ouest, la pente étant d'un mètre par kilomètre. Une ligne de rivage inférieure à environ 20 mètres au-dessus du niveau de la mer a été formée il y a moins de 4,000 ans. Le soulèvement de la partie ouest de l'île Baffin s'est fait lentement comparativement aux zones adjacentes de dispersion glaciaire. Il se pourrait que cela provienne en partie d'un amortissement causé par la calotte glaciaire de l'île Baffin dont la masse était considérable au cours de la période des premiers mouvements. L'auteur a fait la comparaison des vitesses de soulèvement des deux côtés du bassin Foxe et a trouvé qu'elles étaient différentes.

INTRODUCTION

Until this present study, most of the investigations undertaken in the Canadian Arctic have been of a reconnaissance nature. Apart from Løken's work in northeastern Labrador-Ungava (1962) there have been no detailed studies on the direction and magnitude of the tilt of synchronous marine features. Ives (1961), Matthews (1961), Barnett (1963), Harrison (1963) and Barnett and Peterson (1964) have dealt with the deformation of glacial lake shorelines in the interior of Labrador-Ungava, and many observations of the altitude of the upper marine limit have been made, including those of Bird (1954), Craig and Fyles (1960), Sim (1961), Craig (1961), Blake (1963) and Ives (1964). Only limited attempts had been made, however, to note the heights of lower prominent beaches or deltas. The general absence of noticeable raised marine shore features below the marine limit superficially suggests that land uplift was so rapid that the requisite conditions for strandline formation as defined in Scandinavian usage (Løken, 1962, p. 24) did not occur, as strandlines are normally considered to form during a temporary balance between isostatic rebound and eustatic sea-level changes. Bird (1954), however, commented on the occurrence of prominent terraces below 30 metres on the west side of Hudson Bay and the literature contains

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*The substance of this paper was read at the 20th International Geographical Congress in London in 1964 and is included as no. 1324 in *Abstracts of Papers* of the Congress.

FIGURE 1
Location map.

many reports of similarly developed forms below this elevation on Baffin Island.

This paper has four major aims:

- to delimit the Isortoq Phase moraine system along the western coast of Baffin Island.
- to examine the association between this system and the sea level of the time.
- to locate the major strandlines and determine the isobases.
- to examine the nature of isostatic recovery.

Figures 1 and 2 show the location of the area under discussion.

Prior to events discussed in this paper a major glacial stand occurred at the Cockburn moraines about 8,200 B.P.* and was followed by rapid disintegration of the Foxe Basin centre of dispersal (Falconer, *et al.*, 1965a and b). This centre was shifted northeastward onto Baffin Island causing an ice flow from the island into Foxe Basin. The sea encroached upon the isostatically depressed land to heights of more than 90 metres above its present level.

For this study altitudes were levelled at 12 localities (Table 1), and, because of the absence of bench marks or any other official sea-level information, *the sea-level datum used was the lower limit of lichen-covered boulders adjacent to the shore.* Allowance has been made for errors inherent in determining the elevation of a former sea level (Løken, 1962, pp. 29-30) and it is suggested that levelled points used in this study have an accuracy of ± 1.0 metre and aneroid observations an accuracy of ± 2.0 metres.

DELIMITATION OF THE ISORTOQ PHASE MORAINES

Along Steensby Inlet, Grant-Suttie Bay and Bray Island the coast is indented by major embayments (Figure 2) with some coastal cliffs. Elevations may reach 210 metres. Inland, the topography is rugged with steep-sided valleys flanked by bedrock hills, Blackadar (1958), Ives (1964) and Sim (1964) have carried out reconnaissance studies in the

*The abbreviation is accepted as the standard form for the presentation of radiocarbon derived dates. The exact meaning of B.P. is "before present" with "present" being taken as 1950 (cf *Radiocarbon*, vol. 4, 1962, Editorial Statement. *Radiocarbon* is an annual publication of the *Am. J. Sci.*).

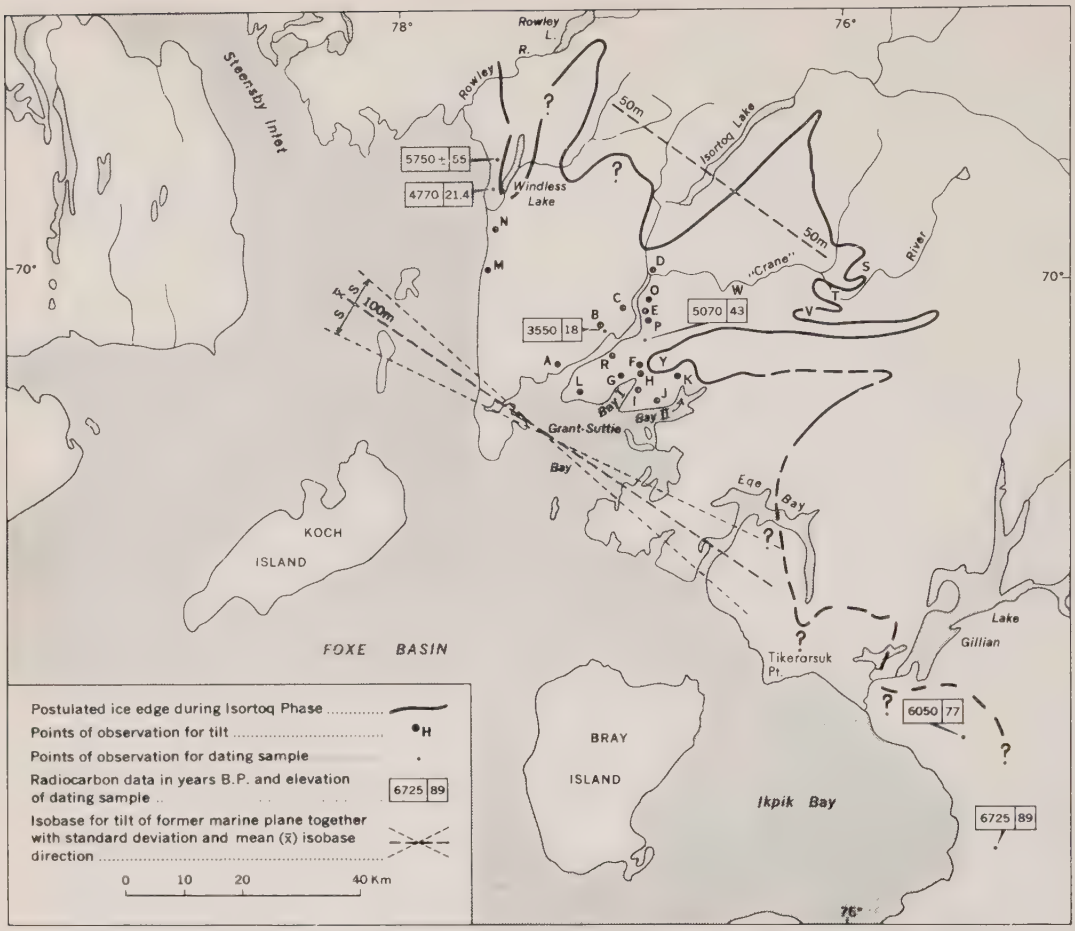

FIGURE 2. Grant-Suttie Bay area showing location of the points surveyed on the marine limit as well as the postulated margin of the Isortoq Phase moraines and the calculated isobases for the associated marine plane.

area. Inspection of air photographs combined with field work suggests the existence of an end-moraine system* which has been traced with some breaks from Windless Lake in the north to beyond Eqe Bay in the south. Figure 2 illustrates the general extent of the system while Figure 3 is a detailed glacial map of a part of the area. Both indicate that the moraines can be traced for at least 100 km. They extend nearly to the coast at the head of Bay II in Grant-Suttie Bay near *K* (Figure 2) where they are associated with a large glacially derived delta formed at the marine limit. Their trend farther south indicates that the upper part of Eqe Bay was probably blocked by the ice and a massive delta at 93.6 metres was built into the late-glacial sea at Tikerarsuk Point (King, 1965, personal communication). In the Isortoq Valley the end and lateral moraines (Figures 3 and 7) slope down at an average gradient of 1:50 from an elevation of 370 metres above Isortoq Lake to about 80 metres near the junction of the "Crane"* and Isortoq rivers (Figure 2). Figure 3 shows that the ice margin at the time the moraines were formed consisted of an 18-km lobe in the Isortoq Lake basin, its southeastern edge running parallel to the lake and with the margin of the plateau ice cap trending north to south from there beyond the "Crane" River. Three morainic loops, *S*, *T* and *V* reflect the digitation of this ice front.

*This term is used to denote a closely spaced moraine sequence which can vary from a single form to a belt of moraines.

*Proposed name, not yet officially confirmed.

FIGURE 3. Glacial deposit map of the Grant-Suttie Bay area, compiled from observations in the field and from interpretation of air photographs.

Table 1
Altitude and nature of the marine limit in Grant-Suttie Bay and Isortoq Fiord

Point (*See* Figure 2)	Elevation (metres)	Method*	Description
Isortoq Fiord			
A	89.2	L	Upper shingle beach
B	75.7	L	Delta surface
C	76.3	L	Stripped bedrock/ground moraine
D	69.5	L	Upper surface terrace/delta
O	72	A	Terrace cut into bedrock
E	75	L	Coarse delta surface
P	76	A	Small delta
R	83	L	Stripped bedrock/ground moraine
L	90	L	Shingle beach/ground moraine contact
Foxetrot Lake			
F	83	A	Shingle beach/ground moraine contact
Bay I			
G	86	L	Shingle beach/end moraine contact
H	84.4	L	Shingle beach/ground moraine contact
I	86.6	L	Delta surface
Bay II			
J	88	A	Shingle beach/ground moraine contact
K	84.5	A	Delta surface
Fellside Lake			
M	91.1	L	Ice-pushed ridge with till above
Windless Lake			
N	92.5	L	Gravel terrace associated with marginal drainage

*L = levelled point.
A = aneroid determination.

Another lobe extended west toward the head of Grant-Suttie Bay. Large deltas (*D* and *W*) and terraces were built up at the ice/sea contact in the Isortoq Valley. It has not been possible to trace the moraine system across the interior plateau to the north, though the massive moraine shown by Ives (1964) along the north and east side of Windless Lake (Figure 3), is probably of the same age. It is not known whether the large delta at the end of the lake (*N*) is synchronous with those (*D* and *K*) farther south.

This moraine phase is called the *Isortoq Phase* after the type locality: its age, importance and relationship to the late-glacial Foxe Basin sea are discussed below. It is stressed that no major moraine systems occur on the immediate proximal or distal side of this moraine system.

LOCATION OF MAJOR STRANDLINES AND DETERMINATION OF ISOBASES

During the summer of 1963 field work was concentrated along Isortoq Fiord and on the peninsulas lying between it and Bays I and II at the head of Grant-Suttie Bay (Figures 2 and 3). The aim was to establish the association between moraines and sea levels. Field work indicated that certain moraines were related to some specific sea level while others in the area showed no such relationship. This difference, occurring within a distance of between 4 and 12 km is important to the interpretation of the glacial history. The deltas associated with the marine limit could also be divided into two categories, small deltas lie along the marine limit on the far distal side of the Isortoq Phase moraines, while massive ones lie adjacent to the Isortoq Phase moraines. The topography of the area is such that only one or two deltas lie on the proximal side of the moraines, particularly in Eqe Bay.

Glacial and marine features in the Grant-Suttie Bay area

In the northeastern section of Grant-Suttie Bay the marine limit is clearly visible with elevations ranging from 90 metres at *L* at the mouth of Isortoq Fiord to 83 metres at *F* in the vicinity of Foxetrot Lake. In most places it is marked by the uppermost of a series of shingle ridges abutting onto undisturbed ground moraine. However, at *G* (Figures 4 and 5) the upper shingle ridge abuts against the distal slope of a small end moraine formed by ice moving

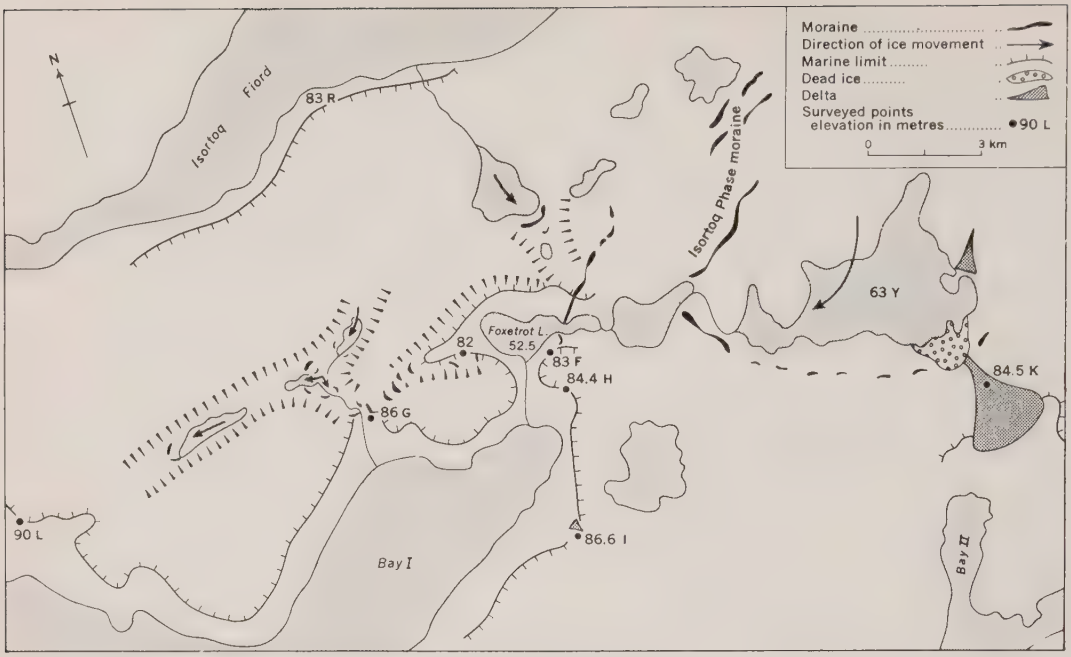

FIGURE 4. Planimetric sketch of glacial and marine features in the vicinity of Foxetrot Lake.

southwest from Foxetrot Lake. At the time this moraine was formed the ice must have extended south into the small bay at the southern end of Foxetrot Lake. Northwest from *G* are other moraines that were deposited at the front of small distributary lobes moving south from a main lobe which at that time occupied Isortoq Fiord. Though these moraines are located near, or at, the marine limit, there is *no* evidence for associate glaciofluvial deposition into the sea level marked by the marine limits. Such evidence might be expected despite possible climatic differences during deposition.

The elevation of the marine limit is 86 metres at *G* and 83 metres at *F* within the Foxetrot basin. Foxetrot Lake is partly bisected by a large end moraine formed of sorted sands and alternating silt bands. The marine limit cuts across the axis of the moraine without any change in elevation and, therefore, must be younger than the moraine. Five km to the east of Foxetrot Lake, a lake (*Y*) lies at an eleva-

FIGURE 5
Series of storm ridges abutting against distal slopes of an end moraine at location G on the north shore of Bay I, Grant-Suttie Bay. Photo taken from above G looking NW up the valley. At right is a very small lake not indicated on Figure 4.

tion of only 63 metres (Figure 4), whereas the marine limit on the delta (*K*) leading from that lake to Grant-Suttie Bay is at 84.5 metres. Ice must have been occupying this lake basin during the deposition of delta *K*. The margin of the ice lobe within the basin of lake *Y* is delimited by lateral moraines of the Isortoq Phase (Figure 4). The sea invaded the upper basin at a later date.

At *I* there is a small delta at 86.6 metres coincident with the marine limit indicating a period of sea-level stability. In Isortoq Fiord at *B* and *E* (Figure 2) deltas occur at the same elevation as wave-swept bedrock/ground moraine junctions and the upper shingle ridge, indicating that the marine limit represents the level of a major strandline rather than a brief period of inundation.

There thus appears to be two distinct sets of moraines: the small moraines near the coast are related to a time when diffluent glaciers penetrated south from Isortoq Fiord which was ice-filled to a height of at least 300 metres, while the Isortoq Phase moraines are associated with deposition at and into a sea level marked by deltas at the marine limit such as at *K* and *D* (Figure 2). The relationship between the two sets and the late-glacial sea level is important; where moraines of the Isortoq Phase approach the coast as at *K* there is evidence of prolonged deposition into a sea having a stable level, but where the small moraines reached the coast there is no evidence of glaciofluvial deposition and the marine limit cuts into and across them.

Figure 4 indicates another important point. Consider points *F*, above Foxetrot Lake, and *R* on the south side of Isortoq Fiord; the height of the marine limit at each site has been levelled at 83 metres. Moraines between the lake and Isortoq Fiord, indicate, however, that the fiord was still ice-filled when Foxetrot basin was open to marine incursion. A difference in elevation of the marine limits might logically, therefore, have been expected in view of the probable time difference of deglacierization.

The explanation of this relationship appears to lie in the probability that the marine limit at the head of Grant-Suttie Bay was established later than the small end moraines and is marked by deltaic forms. As such it does not appear to be metachronous as is usually postulated for arctic Canada, but may represent the synchronous upper limit of a transgressive sea. A further point, emphasized below, is the continuity of the marine limit within the area and the absence of glacial lateral forms.

Glacial and marine features in the Isortoq Fiord area

Isortoq* Fiord, so named because of the muddy, glacially derived water, is a major indentation running northeast from the northern end of Grant-Suttie Bay. Its waters are shallow and boulders are awash at low tide. The tidal range is approximately 2 to 3 metres.

The marine limit is a consistent feature along the entire length of Isortoq Fiord (Figure 6).

*Eskimo name referring to muddy water.

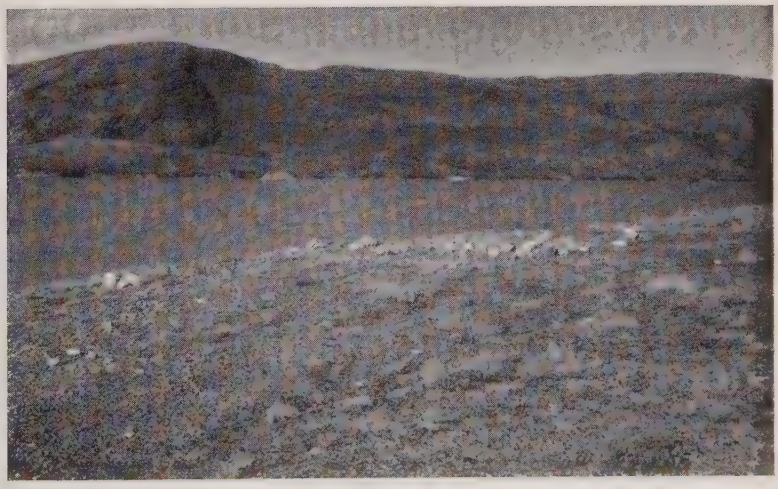

FIGURE 6
Marine limit on the northern side of Isortoq Fiord at location C (76.3 metres). Photograph taken from the delta surface at location E (75.0 metres).

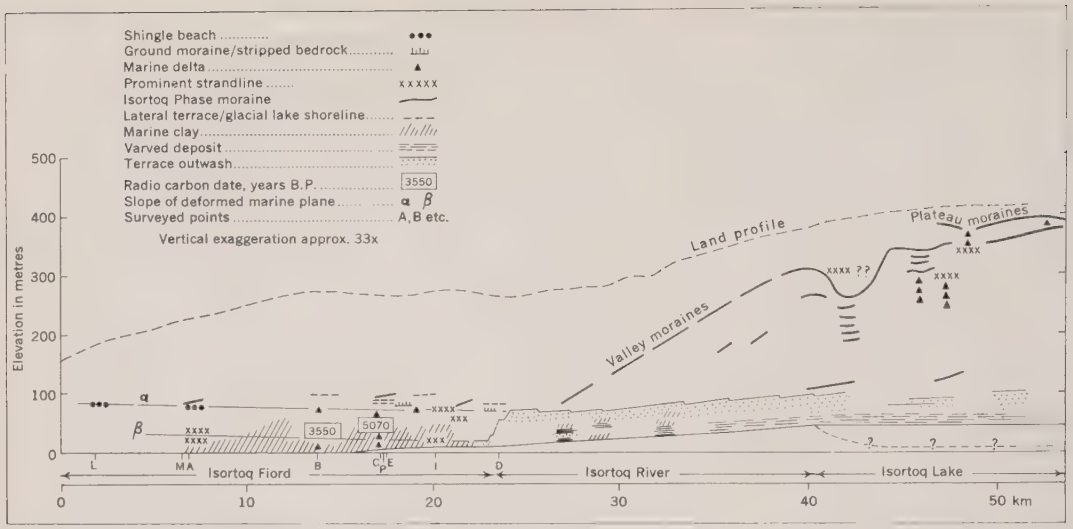

FIGURE 7. Cross-section along Isortoq Fiord as far as Isortoq Lake showing marine and glacial features projected onto a plane parallel to the valley axis.

Figure 7 is a vertical section along the axis of the valley and should be read in conjunction with Figure 2.

At the mouth of the fiord the highest shingle beach abutting against ground moraine (*A*) was levelled at 89.2 metres. At lower elevations, bluffs of thick, massive fossiliferous marine clay are found. The marine limit falls in elevation toward the interior; at *B* (Figure 3) there is a delta at 75.7 metres (Table 1). Above this delta there is a section of lateral terrace or old lake shoreline at 98 metres (Figure 7). In three other locations small stretches of lateral terrace or deltaic remnants lie above the marine limit. That these features are marginal glacial forms rather than of marine origin is shown by the relationship between measured elevations from *C* and those from *E* and *P* on the opposite side of the fiord. At *C* there is a beautifully cut marine limit (Figure 6) marking the junction between wave-swept bedrock and undisturbed ground moraine; the elevation is 76.3 metres. At *E* and *P* the situation is more complex, but it should be noted that the points are at approximately right angles to *C* as judged from the trend of the fiord. At *E* there is a sloping, rather irregular terrace at 97 metres and, below it a small, well-formed delta at 75 metres. There is an upper terrace remnant at 89 metres near *P* with a more pronounced and horizontal feature, a delta remnant at 76 metres which has been taken to mark the marine limit. It is inconceivable that the marine limit varies by 21 metres along a 3-km line perpendicular to the strike of the fiord and clearly, therefore, the marine limit was at about 75 metres, the elevation of the deltas at *E* and *P*.

Farther east, convincing evidence for a prolonged stillstand at this marine limit is a small wave-cut terrace, between 1.6 and 2.0 metres wide, cut into weak bedrock at *O* (Figure 3). Finally, at the junction of the "Crane" and Isortoq rivers the upper outwash terrace on the distal side of the Isortoq Phase moraines is level with a prominent marine limit on the north side of the Isortoq Valley (observation made through a Zeiss N2 level). The outwash surface (*D*) lies at 69.5 metres and there is another terrace 9 metres above it. This latter feature is judged similar to the other terrace forms discussed above which lie above the determined marine limit; they all occur within small tributary valleys and represent lateral ice deposits.

Farther upstream, between the confluence of the "Crane" and Isortoq rivers and Isortoq Lake (Figure 7) the marine clays change and become predominantly varved. In some sections fossiliferous marine clay overlies varved deposits which in turn overlie marine clays. These deposits are inset into a series of outwash terraces 60 to 70 metres high. The outermost outwash at 69.5 metres is associated with the

moraines of the Isortoq Phase. The stratigraphy cannot be fully interpreted because of the lack of three-dimensional sections through the terraces, but a readvance of the ice and a change in salinity could be a sufficient explanation.

In summary, field investigations along Isortoq Fiord and the northeastern section of Grant-Suttie Bay indicate the presence of an extensive upper limit of marine action that is virtually continuous throughout this area. The Isortoq Phase moraines lie inland of this limit and their outwash grades into it. There is no evidence to suggest that the feature was not formed as a single unit. In places the marine limit does not appear to be associated with the pre-Isortoq Phase moraines, rather, the relationship between the moraines and the marine limit indicates that during moraine formation the sea was probably at a lower elevation than during a subsequent period of marine transgression.

The conclusion that the marine limit is contemporaneous throughout the area must not be accepted without scrutiny as it is a concept that runs contrary to most interpretations on the significance of the marine limit. It is understood that upon deglacierization of a coastal area the still depressed land allows the incursion of the sea to a specific elevation for each locality. In arctic Canada it is generally assumed that the sea was at its maximum elevation above present sea level at the time of the deglacierization of the land surface. It would thus impinge on the land immediately upon, and consequent with, the ice retreat. That this may often be the case is not doubted though there are reasonable alternatives. However, the supposition that the maximum sea-level height lay adjacent to the receding ice implies that the marine limit is a time-transgressive feature.

The alternative hypothesis to the proposal that the marine limit is a synchronous feature is that, given constant and rapid ice recession from the mouth of Isortoq Fiord to its head, the end product would be an inclined marine limit caused by progressive uplift concomitant with glacial recession. Whether the marine limit was inclined eastward or westward would depend on the position of the zone of greatest uplift. The existence of a major dispersal centre over Foxe Basin is sufficiently well documented (Sim, 1960, 1964; Ives and Andrews, 1963; Andrews and Sim, 1964) to support the theory that differential uplift would be greatest toward the centre of the basin. Marine incursion concomitant with glacier recession therefore would lead to a decrease in the elevation of the marine limit from the outer to the inner sections of the coast. If retreat had been slow the greater uplift at the mouth of the fiord would have resulted in a greater apparent tilt along the marine limit and more pronounced glacial marginal forms should exist. Furthermore, this raises the question as to whether the ice in the fiord and the diffluent ice in the bay would retreat at an equal rate.

Three of the strongest arguments against the theory of a metachronous marine limit are: (1) the agreement in elevation between points on the marine limit perpendicular to the strike of the fiord proper; (2) the continuity of the marine limit and (3) its even altimetric gradient. It is also difficult to reconcile the existence of glacially-derived deltas, built into the sea, with the concept of a rapidly rebounding coastal area. The deltas, it should be noted, exist along the whole length of the field area and coincide with the marine limit. In themselves they testify to the importance of this limit in the late-glacial history of the area.

It has been concluded, therefore, that, within this area, the marine limit represents an important strandline and is related to a particular moraine phase. This conclusion gains support from a review of the literature, some of which indicates relationship between glacial advance and the formation of some prominent marine forms. Thus in Ullsfjord, Norway, Holmes and Andersen (1964) have shown that the main beach level is nearly continuous for 35 km and that it cuts across older moraines and gravel deposits and is incised into bedrock. It also forms the marine limit in the area and ends at the Skardmunken moraine. In northeastern Labrador-Ungava, Løken (1962) has shown the relationship between readvance phases and specific strandlines, while Sissons (1963) in Scotland points to the relationship between the ice front of the Perth readvance and a strandline in the Firth of Forth. At least in the inner sections of the Forth the strandline constitutes the marine limit. Recently, Sugden and John (1965) postulated that strandlines in east Greenland should be correlated with glacial readvan-

ces, while Thorarinsson (1951) related a marine transgression in north and west Iceland to the advance of the inland ice. More recently, Parry and Macpherson (1964) postulated that isostatic depression occurred in front of the ice advancing to the line of the St. Faustin-St. Narcisse moraine in Quebec.

Such evidence indicates that crustal response to loading may be a delicate adjustment and one that may be affected by the increase in mass of an ice cap and the consequent glacial readvance. The increase in loading results in a depression of the land surface that might or might not be associated with eustatic sea-level changes. The net effect would be a marine transgression and the formation of major shore forms when the ice reached an equilibrium condition after a readvance. The size of the moraines and deltas of the Isortoq Phase testify to a stillstand at this position. This hypothesis appears essential to explain strandline formation in areas where uplift was considerably greater than eustatic sea-level rise. On west Baffin Island initial uplift was about 3.0 metres/century at a time when world sea level was rising by 1.2 metres/century (Shepard, 1960). Uplift curves, it is suggested, indicate that the immediate response to unloading is a rapid uplift while the effect of loading, such as would be caused by an increase in ice mass, would be a rapid depression of the crust. An indication of the great increase of mass which can result from a relatively small readvance is shown by the following: assuming that ice is a perfect plastic substance it can be shown that, with a circular ice sheet, a 10-km readvance of an ice cap with a radius of 190 km would increase the mass by 12 per cent.

Radiocarbon dates indicate that the deglacierization of this coast occurred more than 6,725 years ago (Sim, 1964), a date obtained from shells 15 metres below the marine limit in Ikpik Bay (Figure 2) on the distal side of the Isortoq Phase moraines. This would place the deglacierization of the coast and the formation of the Isortoq Phase moraines within or near the hypsithermal period. Recently dates of 5,000 and 5,500 B.P. have been obtained from proximal sites and may be another indication of a prolonged stillstand at the Isortoq Phase moraines. The tentative dating of the Isortoq Phase indicates that it may be contemporaneous with readvances in Alaska, Ellesmere Island (Fyles, 1964, personal communication) northern Greenland (Davies, 1964, personal communication), and eastern Baffin Island (Løken, 1965, personal communication).

The following events may represent the possible sequence. The ice in Foxe Basin rapidly disintegrated until the margin rested on the west coast of Baffin Island. A major trunk glacier in Isortoq Fiord sent diffluent glaciers south to form small moraines at the head of Grant-Suttie Bay. Sea level was below the present marine limit. The ice front retreated from the fiord toward the interior. This retreat was followed by a readvance to the line of the Isortoq Phase moraines. In response to the increase in glacier volume a reduction occurred in the rate of isostatic rebound and, probably, even renewed depression of the crust so that the sea transgressed to the line marked by the marine limit. No figure can be given for the vertical extent of the maximum sea-level height reached during the transgression but 3 to 9 metres would accommodate an interval of 100 to 300 years between the pre-Isortoq and the Isortoq Phase moraines. Vogt (1933) concluded that, in southeast Greenland, the increase in ice volume after the hypsithermal resulted in a decreased rate of uplift. This view is in agreement with observations which indicate the association of strandlines and specific moraine phases.

DETERMINATION OF ISOBASES

Upper strandline

The highest marine features shown on Figure 7 rise southwestward at a steady rate along Isortoq Fiord, from 69.5 metres to 89.2 metres over a distance of 24 km from *D* to *A*. The upper marine features are well developed and can be followed with only limited breaks. Their form varies to include a wave-cut bedrock terrace, deltas of varying size, successions of storm ridges abutting against undisturbed small end moraines, ground moraine or bedrock knolls, and, finally, the junction between stripped bedrock and ground moraine (Table 1).

To determine whether or not the marine limit represented a consistently deformed plane, series of approximately equilateral triangles

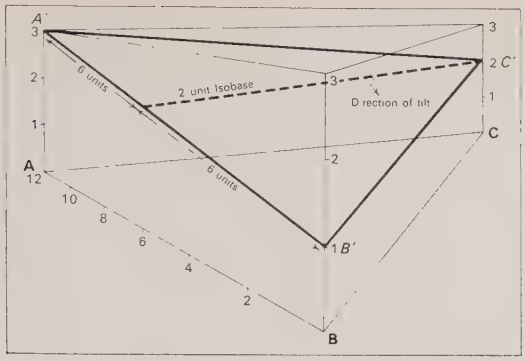

FIGURE 8. Isometric drawing of the tilted plane method of isobase calculation.

were constructed from the network of surveyed points shown in Figure 2 and Table 1. The magnitude and direction of tilt were derived from each triangle (Løken, 1962). Figure 8 is a specific illustration of the technique, employing simple units. A former marine plane is represented by the triangle A′B′C′ which has been tilted by differential isostatic uplift so that A′ lies at three units above the horizontal datum ABC, B′ at 1 unit and C′ at 2 units. To determine the position of the unit-2 isobase, the line between A′ and B′ is bisected and a line is drawn from C′ to that point. This then is the orientation and position of the unit-2 isobase. The other isobases are then drawn parallel to it and the direction of tilt is calculated from the difference in elevation between two successive isobases divided by the distance between the isobases.

The configuration of the area allowed 21 triangles to be constructed and the basic results are presented in Table 2 while the directions of tilt are graphically portrayed in Figure 9. The results are consistent and support the contention that the marine limit is a single strandline. The calculations indicate an apparent deformation of the plane of the marine limit upward toward S 35° W at 1.0 ± metres/km (Figure 10, the α line, *see* also Figure 7). This gives an isobase direction of N 55° W which is slightly oblique to the coastline (Figure 2). The direction and slope of the deformation is assumed to be the result of glacial unloading and isostatic rebound. As such, the results are consonant with the hypothesis proposed by Sim (1960) and by Ives and Andrews (1963), that Foxe Basin was a major glacial dispersal centre during the last glaciation. The bearing of the line of deformation could indicate a major centre over Foxe Basin, but without other orthogonals it is impossible to determine the position of the central zone of uplift.

Table 2
Resolution of triangles

	Isobase direction	Direction of tilt	Tilt metres/km
Mean	N 55° W	S 35° W	1.02
Standard deviation	±8°	±8°	±0.15
Range	29°	29°	0.59
Number of observations = 21			

Figure 10 is an equidistant diagram drawn along the calculated direction of tilt in Isortoq Fiord and the α line points representing the marine limit have been projected onto this plane. There is close agreement between the line and the points. As such, the method of triangles has several advantages over the calculation of the line of regression, the principal

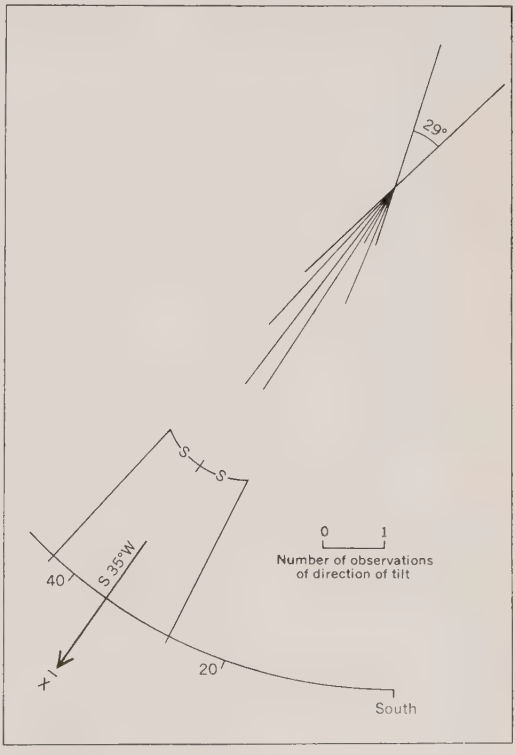

FIGURE 9. Spread of the determinations of crustal deformation derived from surveyed points in the field area.

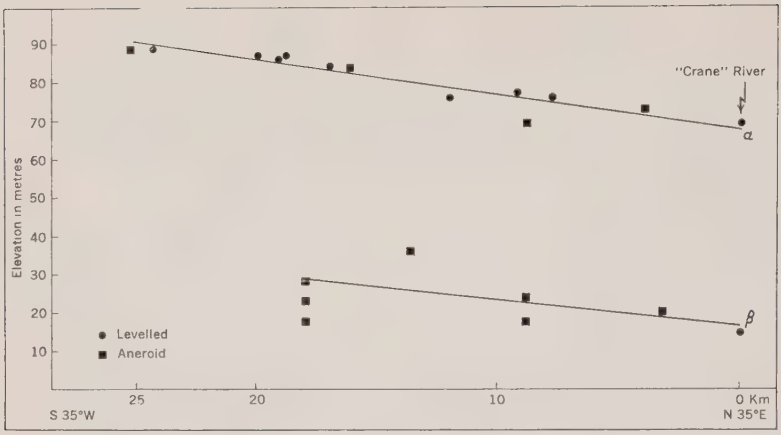

FIGURE 10
Equidistant diagram drawn in the plane S 35° W to N 35° E along the mean direction of tilt with points in Isortoq Fiord projected onto the diagram.

one being that the plane of projection is determined by the results, whereas with regression analysis the result is determined by *choosing* the most suitable projection.

The extended diagram (Figure 11) is drawn in the plane of maximum tilt, that is S 35° W to N 35° E in the vicinity of Isortoq Fiord with elevations on major marine deltas and marine limits in the surrounding areas included. These observations have been taken from the reports of Ives (1964) and Sim (1964) and cover a distance of 240 km along the coast. No attempt has been made to compensate for the curvature of the isobases nor for the probable curvature along a line at right angles to the isobases. In this latter case the deformation is probably proportional to the square of the distance from the former ice margin. Assuming, however, that the isobases are equally spaced within the horizontal distance discussed here, and that the centre of curvature is to the southwest, points on the same tilted strandline would, by implication, appear below the line of projected tilt. The displacement of points is also a function of the distance from the line of projection. The probable error can be easily

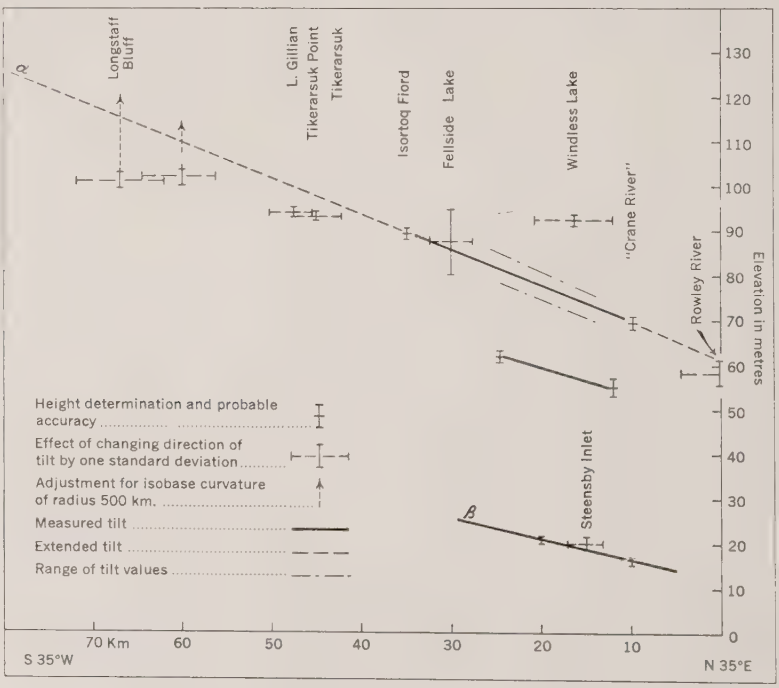

FIGURE 11
Extended diagram along the plane S 35° W to N 35° E with points from sites north and south of the field area projected onto it.

calculated. If the radius of curvature is 500 km, the error over a distance of 100 km is 10 km in location, or an error in altitude on the extended diagram of approximately 10 metres. The horizontal error increases so that, 200 km from source, the location is 41.5 metres too low on the diagram. As the actual curvature of the isobases is not known a precise error cannot be established.

The coincidence of the extended tilt of the upper strandline i.e., the α line (Figure 11) and the surface of the large Tikerarsuk and Lake Gillian deltas (King, personal communication, 1965) indicates that during the Isortoq Phase the ice lay in the Gillian basin and at least partially blocked Eqe Bay. The position of the ice margin across Eqe Bay (Figure 2) was inferred earlier from the trend of the moraines. Some of the sites plotted on Figure 11 lie south of the area of present field operations and therefore are not shown on Figure 2.

Figure 11 indicates the position of these points and the possible correction for isobase curvature. Assuming an isobase radius of 500 km, which is purely conjectural, both points now lie just above the extended line of tilt, although it should be noted that the position of the points also depends on the selected plane of projection. The presence of a moraine has been noted on air photographs near the head of Piling Bay (69° 02′ N, 74° 45′ W); it trends approximately parallel to the coast and may be contemporaneous with the Isortoq Phase moraines to the north. The above points lie on the distal side of the Piling Bay moraine. Field work should establish the validity of this hypothesis and should enable the isobase curvature to be calculated. A comparison of the results from 1963 and 1965 indicate that the over-all isobase trend is N 40° W.

In the north the diagram is difficult to interpret and its accuracy depends on the selection of the projection plane. A large but poorly proportioned triangle was drawn on observations from the Windless Lake delta, the "Crane" River terrace outwash and the delta at point *L* at the head of Grant-Suttie Bay. If the three features are of the same age and relate to the same level they should give answers comparable to those in Table 1. The results are as follows: direction of the isobases N 53° W; amount of tilt 1.36 metres/km. The strike of the isobases agrees with the previous results, the amount of tilt being within two standard deviations of the original results. The Fellside Lake delta (69° 59′ N, 77° 34′ W) has an elevation of 88 ± 8 metres near *M* (Figure 3), and its position on the extended line could be fortuitous. The delta was deposited by material originally emplaced by ice that had moved south from the Windless Lake basin and therefore it is similar in age to the Windless delta. Though a firm conclusion is not possible at present it may be that the upper Windless Lake delta is synchronous with the α line. In this connection the map of Ives (1964, Figure 2) indicates that moraines, probably of the Isortoq Phase, end near the northern end of the lake and this would agree with the above interpretation. Further comment is difficult because of the width of the confidence bands for tilt (Figure 12) and the change in position of points as the plane of projection is changed by rotation through 8 degrees on either side of S 35° W.

Lower strandline

There is some evidence for at least two lower strandlines though the quantity of data is meagre. On the east side of Isortoq Fiord near the "Crane" River there is a broad wave-washed terrace at 55 metres; farther down fiord at *P* (Figures 2 and 3) there is a main delta flat at 64 metres. No other prominent levels are found above this until the marine limit is reached and none below until a series at about 20 metres is encountered. The gradient between these two observations along a true bearing of 215 degrees is 0.7 metre/km.

At lower elevations there are series of well developed delta flats, terraces and beaches. At the confluence of the "Crane" and Isortoq rivers a prominent marine delta terrace level lies at 16 metres. Three km downstream is a terrace at 20 metres cut into marine clay and overlain by gravels (Figure 7). At *E* the delta has two lower levels at 22 metres and 15.5 metres. Finally, at the head of Grant-Suttie Bay near *L* and *G*, there is a pronounced bench beneath the coastal cliffs with levels at 30, 22 and 16 metres. The equidistant diagram (Figure 10) indicates the position of the points. It is clear that they could be linked by several possible lines. The lower strandline, the β line, in Figure

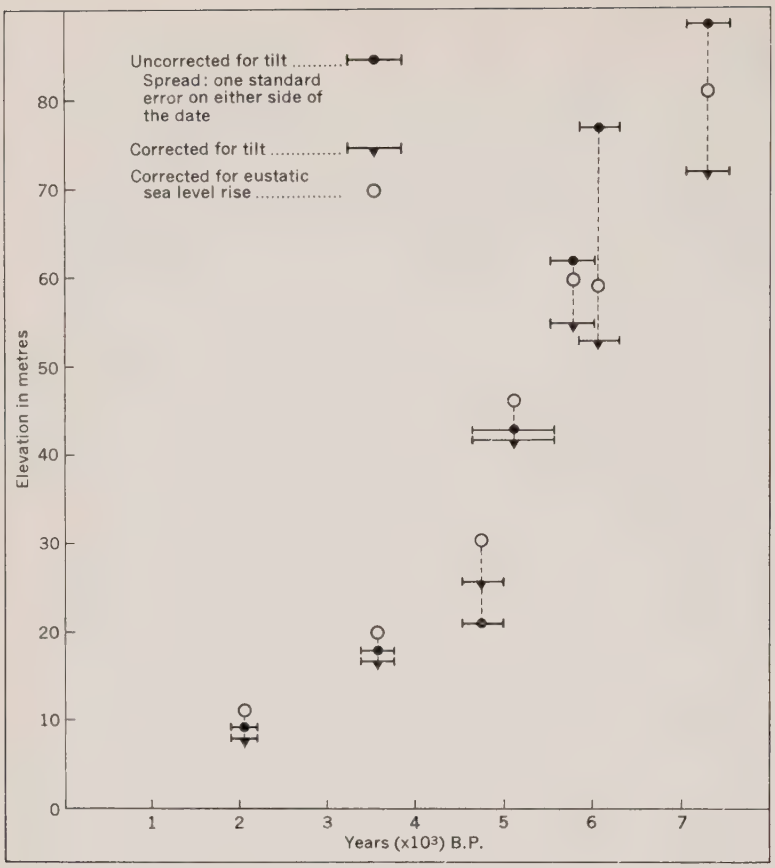

FIGURE 12
Form of isostatic recovery of west Baffin based on seven radiocarbon dates and adjusted for tilt and eustatic sea-level changes.

7, links the best development. It has a gradient of 0.33 metre/km inclined upward toward the centre of Foxe Basin.

Ives (1964) mentions the existence of prominent terraces along a portion of the Steensby Inlet coast with elevations of 20 to 23 metres and 29 to 32 metres. The lower feature is a pronounced constructional bench and is very extensive. It falls on the projected β line (Figure 11).

Two dates have been obtained from material within the constructional bench along Steensby Inlet and from a delta on the north side of Isortoq Fiord. The former is from marine shells and gives an age of 4,700 $\pm$ 210 years (GB (I-487), Ives, 1964); the latter is from plant remains 3,550 $\pm$ 200 years old that have been washed into the deltaic bedding (GB (I-1247), Table 3). The shells were not *in situ* and could possibly date from a period immediately prior to the construction of the bench. Of the two, the plant remains should give the more accurate date. In consequence the β line is probably less than 4,000 years old. It might be related to

Table 3
Location, material and radiocarbon age of samples from dated levels

Metres	GB lab. no.	Locality	Age in years	Material	Lab. C-14 no.	Latitude	Longitude
89	VWS-61-1S	Ikpik Bay	6,725 $\pm$ 250	shell	GB (I-406)	69°10′N	75°28′W
77	VWS-61-2S	Ikpik Bay	6,050 $\pm$ 250	shell	GB (I-405)	69°18′N	75°37′W
55	JDI-61-3S	Steensby Inlet	5,750 $\pm$ 250	shell	GB (I-486)	70°09′N	77°35′W
43	JDI-63-7S	Isortoq Fiord	5,070 $\pm$ 450	shell	GB (I-1244)	69°55′N	76°54′W
21.4	JDI-61-4S	Steensby Inlet	4,700 $\pm$ 210	shell	GB (I-487)	70°09′N	77°35′W
18	JTA-63-1P	Isortoq Fiord	3,550 $\pm$ 200	plants	GB (I-1247)	69°56′N	77°02′W
9.2	VWS-61-3S	Piling Lake	2,050 $\pm$ 170	shell	GB (I-489)	69°02′N	75°02′W

a prolonged glacial stillstand or readvance in early sub-Atlantic times, though this conclusion needs further support.

SHELL DETERMINATIONS

Members of the Fifth Thule Expedition to Baffin Island and Melville Peninsula collected marine shells from raised beach deposits around Foxe Basin. Laursen (1946) identified the shell collection and suggested that high arctic marine conditions were followed by a warmer period when the sea was between 30 and 50 metres above present levels. He cites *Astarte montagui* (Dill) var. *striata* (Leach) Sars as an indicator of warmer conditions. At lower levels he finds evidence of warm and sub-arctic periods with a deterioration in temperature below 12 metres. Judging from the uplift curve from Melville Peninsula (*see* Figure 14), a sea level 12 metres above present sea level dates at approximately 1,000 ± years B.P. The warm phase of Laursen (1946) may date from between 3,800 and 2,600 years B.P. On west Baffin Island *Astarte montagui* var. *striata* is found at elevations which date from approximately the same period. Most of Laursen's observations apply to collections from the west side of Foxe Basin. These conclusions have important implications, although it is difficult to say how far they will be modified by the increasing number of species determinations from arctic areas. Inferences on climatic change based on mollusca are still largely tentative because of inadequate knowledge of species distribution.

Both Sim and Ives collected shell samples from various elevations along the west coast of Baffin Island and these samples were examined by F. J. E. Wagner of the Geological Survey of Canada. Table 4 contains the relevant information, data in the "Present day" column being taken from Ellis (1960) for Frustration Bay, Rowley Island and Igloolik. As the samples were collected for radiocarbon dating rather than for the analysis of faunal composition they probably do not include all species present at the sites. Wagner comments (1964, personal communication) that they are all common low-arctic, shallow water species and adds further, "The assemblages are really too small for positive conclusions to be drawn, but they do suggest no change in conditions between sea level and the highest collections".

NATURE OF ISOSTATIC RECOVERY

Radiocarbon dating has allowed the rate of land uplift to be determined in several areas (Lee, 1962; Washburn and Stuiver, 1962; Farrand, 1962; Olsson and Blake, 1962; Henoch, 1964; and Løken, 1965). Ives (1964) drew a provisional curve for northeast Foxe Basin based on five shell samples collected from scattered localities, two from Steensby Inlet (Figure 2) and three collected by Sim from Ikpik and Piling bays to the south of the

Table 4

Determinations of shell species, West Baffin Island (F. J. E. Wagner)

Date (B.P.)	6,725 ± 6,050			4,700	4,025	2,000	Present day
Elevation (metres)	84	74	30	21	0	3	
Pelecypoda							
Hiatella arctica Linné		+	+	+	+	+	+
Mya truncata Linné			+	+			+
Mya truncata var. *uddevallensis* Forbes					+		
Mya sp.	+	+				+	
Macoma calcarea (Gmelin)		+			+		+
Clinocardium ciliatum (Fabricius)				+			+
Astarte borealis Schumacher					+		+
Astarte montagui var. *striata* Leach			+				
Astarte montagui var. *warhami* Hancock			+				
Astarte montagui			+				+
Nucula sp.							+
Gastropoda							
Lepeta caeca (Müller)				+			
Cirripedia							
Balanus crenatus Bruguière				+		+	
Balanus sp.		+					

present field area. Ives justified the drawing of this curve on the basis of the known pattern of deglacierization. Ideally, the most suitable uplift curve would be constructed from samples collected at the one site (Løken, 1965).

Subsequent field work led to two additional dates at 43 metres and 18 metres (Table 3 and Figure 12). Their position on the graph does not materially alter that prepared by Ives (1964). However, further refinement in the drawing of the curve is possible because of the determination of crustal deformation at the α and β lines. All points have been projected onto the line of extended tilt (Figure 11) and adjusted to a site near A in Isortoq Fiord. The improvement in the fit of the points is shown in Figure 12 but even without this correction and without the eustatic sea-level correction, the initial curve is quite acceptable. The final correction is that for sea-level fluctuations using Shepard's data (1960), and the result is a smooth curve reflecting the rate and amount of uplift for the site. Uplift along the west coast was initially moderately rapid and amounted to between 2 and 3 metres/century for the first 2,000 years following withdrawal of the inland ice. There is an inflection in the curve at about 4,000 B.P., though not as pronounced as in the curve from Melville Island (Henoch, 1964). Rebound has continued at a decelerating rate averaging 0.5 metre/century. The angle of the curve at the origin suggests that uplift is still continuing and further support of this comes from an observation by Manning (1950) of an Eskimo fish trap about 6 metres above high tide at the head of Piling Bay.

Uplift curves plotted as in Figure 12 may be approximated as straight line graphs on semi-logarithmic paper and may be expressed as exponential functions of the form:

$$\text{Uplift} = Ce^{(2.303)kt}$$

where C is the intercept on the y axis, k is the slope and t the time in years. Figure 13 illustrates a series of uplift lines from several different areas. These lines represent "best fit" estimates and errors include those in the original data as well as those due to the assumption that the data may be fitted to series of exponential curves. Though they begin rebound at different times the slope of the lines and their intercepts allows their main characteristics to be discussed. Sources used in the construc-

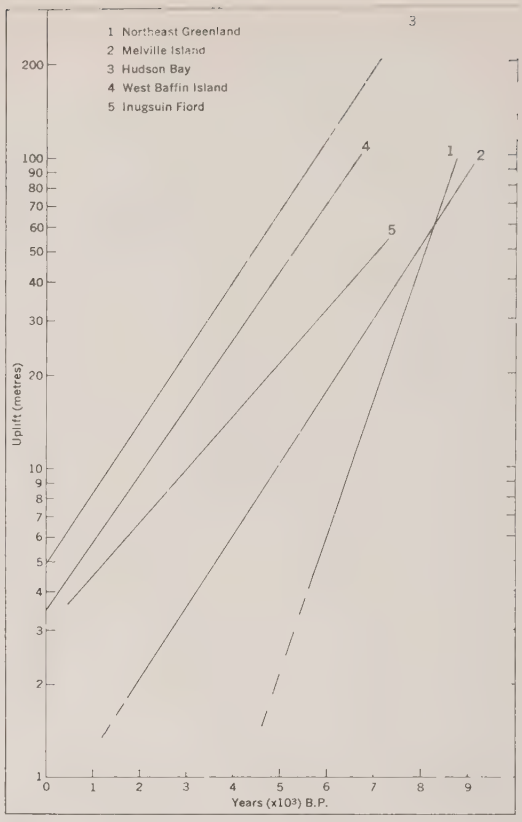

FIGURE 13. Comparative isostatic recovery in arctic Canada plotted on semi-log paper.

tion of these lines were northeast Greenland (Washburn and Stuiver, 1962); Melville Island (Henoch, 1964); Hudson Bay (Lee, 1962); west Baffin Island (this paper and Ives, 1964), and east Baffin Island at Inugsuin Fiord (Løken, 1965).

Two of the curves, numbers 1 and 5, are characterized by distinctive slopes: the former, northeast Greenland, fits an expression with k equal to 0.00087 while rebound in the latter, Inugsuin Fiord, has been extremely slow with a k value of 0.00039. Melville Island has a similar value for k. The rate of uplift in Hudson Bay is rapid, with updoming still continuing (Barnett, 1966) whereas it appears to have ceased on Melville Island (Henoch, 1964). Baffin Island is experiencing a slower isostatic rebound than Hudson Bay with uplift being greater on the west side of the island than on the east. As Foxe Basin was a major ice dispersal centre during Wisconsin time (Ives and Andrews, 1963; Andrews and Sim, 1964; and

Falconer *et al.*, 1965b) the rate of uplift for west Baffin Island is surprisingly low. In theory the rate of free rebound should be proportional to the weight of ice over each site and such is the form of a major ice cap that large differences in ice thickness cannot readily be explained for the central dispersal areas. Problems of interpretation can, however, occur because only a limited part of the total uplift may be empirically derived.

Analysis is taken further in Figure 14. Data from along the coast of east Melville Peninsula (Craig, 1965; Sim, 1961; Farrand, 1962; and Rainey and Ralph, 1959) have been plotted alongside that from the west side of Baffin Island, both are "best fit" curves and points are adjusted for eustatic sea-level rise. The curve for Melville Peninsula has been drawn on the same assumption as that for west Baffin Island, i.e., that uplift has been essentially the same along the entire coast. Standard errors of estimate for the Melville Peninsula curve is ± 11 metres and for west Baffin Island ± 14 metres. Both curves have been constructed from points along a 200-km stretch of their respective coasts. The upper date is taken as approximately the age of the marine incursion.

Radiocarbon dates suggest that both sides of Foxe Basin were deglacierized at the same time and the difference in amount of uplift cannot be a time function. It is possible that the Baffin ice was grounded in the shallow waters of the west coast and took longer to disappear than ice over coastal Melville, but the dates of 6,800 (Craig, 1965) and 6,725 B.P. (Table 3) that mark the oldest and highest shell collections on either coast are so close to the respective marine limits that they are good approximations for the date of ice withdrawal. Retreat in the basin appears to have progressed northward from Hudson Strait and probably took the form of an east-west oriented calving front with residual masses isolated on Melville Peninsula and an ice cap of major proportions covering most of Baffin Island. North to south striations on islands in the basin (Mathiassen, 1933; Burns, 1952) and on Baffin Island itself are evidence for such a pattern of retreat. The difference in the amount and rate of rebound (Figure 14) may thus be due to the difference between free uplift on Melville Peninsula and a dampened uplift on Baffin Island related to

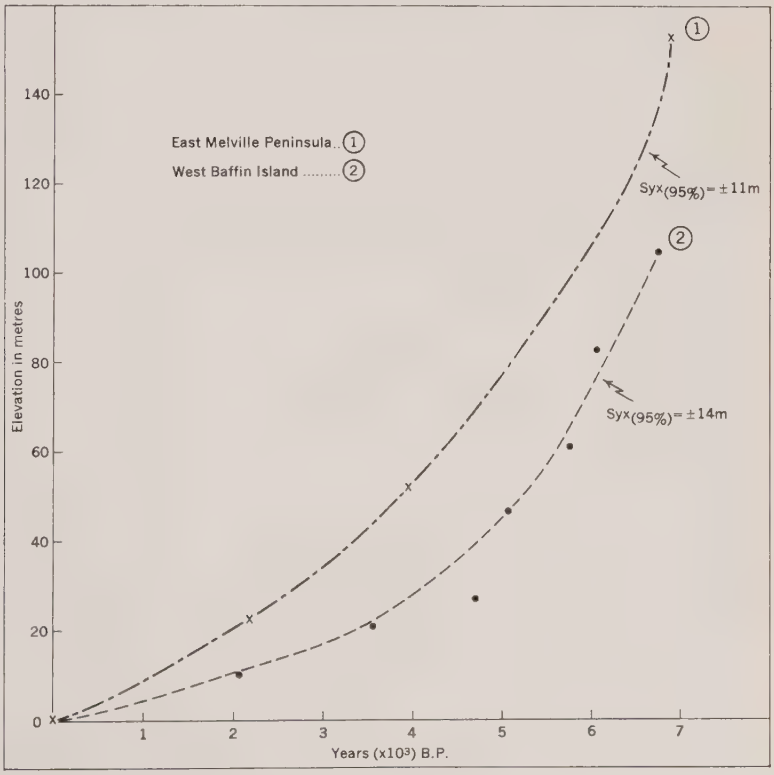

FIGURE 14
Comparative uplift from the east and west sides of Foxe Basin.

the mass of the Baffin ice cap. Differentiating du/dt in order to establish the rate of uplift (Table 5) for specific periods indicates a significant difference between the two sets of data. The figure of about 0.80 metre/century for the uplift of eastern Melville Peninsula compares with the revised estimate for rate of land uplift at Churchill based on tide gauge readings (Barnett, 1966).

Table 5

Probable rates of uplift after deglacierization in metres/year at specific times

Time $\times 10^3$ years	1	3	6.7
West Baffin Island	0.03	0.01	0.004
East Melville Peninsula	0.06	0.02	0.008

Another explanation for the observed differences may be that the Foxe Basin ice dispersal centre lay asymmetric to the land areas and that there was a real difference in ice mass over areas during the maximum glaciation. However, the rate of rebound indicates an initial difference greater than could reasonably be expected in light of the slight surface gradients on large ice caps. The two rates of uplift have produced a tilt of at least 1:4,000 across the basin from east to west, a minimum figure as Melville Peninsula probably lay west of the ice divide. These areas lie between the Cockburn moraines (Falconer, *et al.,* 1965b) and the Isortoq Phase moraines.

The low marine limit of west Baffin Island is at variance with the postulated glacial maximum history of the area and the writer suggests that this is a combined function of the retention of a late glacial ice mass and the maximum ice centre being located west of Baffin Island. Ives (1964), however, indicated that the explanation might lie in the late deglacierization of the coast. This suggestion is tenable, but is only part of the answer.

Uplift of western Baffin Island was initially slow compared with other areas central to the Wisconsin ice sheet (Lee, 1962). This phenomenon cannot be explained solely by the later deglacierization of Baffin Island and must be related to the differences in rebound. It is now known that central Keewatin was deglacierized extremely rapidly between 8,500 and 7,000 years ago (Falconer, *et al.,* 1965a; Falconer *et al.,* 1965b). Thus isostatic readjustment could proceed unchecked although Baffin Island retained a slowly retreating ice cap that had sufficient mass to affect crustal movement. Because of the retardation of uplift the isostatic curve of west Baffin Island is not marked by a sharp inflection (Washburn and Stuiver, 1962; Henoch, 1964) but is much smoother than Melville Peninsula, implying rapid, present-day uplift.

Uplift curve and strandline formation: There appears to be an anomaly between data presented in the uplift curve and geomorphic evidence for phases of isostatic equilibrium in the form of major terraces or deltas. The acceptance of the smooth uplift curve for the west Baffin Island coast does not necessarily preclude relative sea-level stability at specific periods. It has been argued in this paper that such phases may result from glacier readvance, time spans of between 100 to 300 years being adequate to create significant shoreline and depositional forms.

Another point worthy of comment concerns the absence of major strandlines in arctic Canada compared to the number observed in Scandinavia. In the latter area detailed investigations have documented a series of stillstands and marine transgressions, while in arctic Canada such evidence is slight and may in part reflect the difference in areal extent and amount of research. However, a more important difference is the time of deglacierization of the two areas. At the time of the rapid deglacierization of arctic Canada, which is dated between the stand at the Cockburn moraines, approximately 8,500 and 6,800 years ago, uplift in many parts of Scandinavia had been proceeding for at least 2,000 years. The area of the ice cap during the Cockburn Phase was 3.7×10^{12} m^2 and the melting of this ice mass would have resulted in an estimated 16 $\pm$ metre rise in world ocean level or 1.0 metres/century. This rapid release of water appears to be reflected in many of the published eustatic sea-level curves for the period 8,500 to 7,000 B.P. Such a rise in ocean level would be insufficient in itself to cause marine transgressions in areas of central arctic Canada because they were still in the initial phase of rapid uplift (6.0 to 2.0 metres/century), but in northern Europe such an event must have had important conse-

quences in the coastal areas whose isostatic recovery was less than the oceanic rise. In peripheral areas of arctic Canada isostatic/eustatic phases could have resulted in relative sea-level stability while in central areas glacial/isostatic mechanisms appear essential for strandline formation.

Direction of tilt determined by uplift curves: The increasing number of uplift curves may be utilized to gain information on the direction, and to a lesser extent on the magnitude, of isostatic deformation. The problem is only discussed here in order to compare the results with those determined from geomorphic evidence.

Three uplift curves are presently available in north Baffin Island: the west Baffin curve (this paper), the Inugsuin Fiord or east Baffin curve (Løken, 1965) and the Tay Sound or northern Baffin curve (Falconer, 1965, personal communication). These curves may be approximated and differentiated to obtain the rebound velocity at any instance of time. Thus 5,700 years ago west Baffin Island's rebound velocity was approximately 0.03 metre/year while at both Inugsuin Fiord and Tay Sound it had a value of 0.01 metre/year. Clearly there was an increase in rate of uplift towards the west and shore deposits from this period will show a westward inclination. The line of equal velocity strikes N 45° W to S 45° E, which is the direction of the isobases determined by other evidence (Figure 2). Conversely, the direction of tilt of the west Baffin Island coast suggests that uplift of eastern sections must have proceeded at a slower rate. Løken's (1965) results show this to be the case.

CONCLUSIONS

The main conclusions may be summarized as follows:

1. In the vicinity of Grant-Suttie Bay and Isortoq Fiord a major moraine phase, the Isortoq Phase, was associated with a former sea level coincident with the marine limit. This strandline, the α line, cuts across older moraines and is marked by deltas, a wave-cut bedrock terrace and shingle beaches. It is nearly continuous for about 30 km. This marine plane has been deformed by isostatic recovery so that it is now inclined toward S 35° W at 1.0 metres/km, i.e., toward the centre of Foxe Basin. A lower strandline, the β line, is tilted in the same direction at 0.3 metre/km and there is some evidence to suggest an intermediate strandline tilting S 35° W at 0.7 metre/km. These are the first detailed observations of this nature from the Canadian arctic. The three strandlines have average elevations of 75, 58 and 20 metres in middle Isortoq Fiord (near *C*, Figure 2).
2. The use of the extended diagram permits discussion of the relationships of other coastal areas along the west coast to the ice margin during the Isortoq Phase.
3. The equating of the marine limit with a strandline may be best explained by an increase in ice volume and a concomitant reduction, or even reversal, in isostatic recovery. Thus some strandlines may be explained by assuming a rapid response of the crust to even a small increase in load. This proposal is necessary to explain the association of specific strandlines and moraine phases especially during isostatic readjustment when uplift would normally exceed world-wide sea-level rise.
4. Radiocarbon dates indicate that the Isortoq Phase is younger than 7,000 B.P. and older than 5,500 B.P. and this also gives an estimated date for the α line. The β line is between 3,500 and 4,000 years old. Because of a persisting ice mass on Baffin Island initial isostatic recovery was less rapid than that of other comparable areas. The reduction in recovery may explain in part the difference in elevation of the marine limit on the two sides of Foxe Basin. Uplift is continuing at a relatively rapid rate of 0.4 metre/century.
5. The Isortoq Phase occurred during the hypsithermal period.
6. This study further stresses the contrasts mentioned by Ives and Andrews (1963) and by Ives (1964) between Baffin Island and the adjoining mainland. Not only was Baffin Island predominantly ice-covered during the Isortoq Phase 7,000 years ago, a time when the Keewatin ice divide had disappeared, but glacial readvances occurred during a general recessive period between then and the present day.

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PRESERVATION OF VEGETATION AND PATTERNED GROUND UNDER A THIN ICE BODY IN NORTHERN BAFFIN ISLAND, N.W.T.

G. Falconer

ABSTRACT

A thin ice body in northern Baffin Island is undergoing rapid recession revealing undisturbed patterned ground features and vegetation. A sample of moss thus exposed has a radiocarbon age of 330 ± 75 years, and supports previous estimates of the occurrence of a markedly more nival period in parts of arctic Canada two to three centuries ago.

RÉSUMÉ

Une mince couche de glace dans le nord de l'île Baffin recule à un rythme assez rapide et laisse à découvert un sol structuré et de la végétation. Un échantillon de mousse soumis à la radiodatation au carbone a donné un âge de 330 ± 75 ans appuyant ainsi les hypothèses antérieures au sujet de l'existence d'une période nivale beaucoup plus intense dans certaines parties de l'Arctique, il y a deux ou trois siècles.

Most definitions of the term "glacier" imply evidence of present or former motion of the ice. There is, however, a type of thin stagnant ice cover in arctic Canada which displays no obvious indication of past or present movement. Such thin ice patches and ice sheets occur in northern Baffin Island, Devon Island, Ellesmere Island (Smith, 1961), Axel Heiberg Island (Beschel, 1961), and some other parts of the Queen Elizabeth Islands in Canada (Saville, 1961; Roots, 1963). Elsewhere they have been reported from Spitsbergen (Glen, 1941) and Antarctica (Stephenson, 1961; Black and Berg, 1963). They range in size from small accumulations of snow and ice a few metres in width to ice bodies covering many square kilometres. Some of them are undergoing thinning or rapid marginal recession at the present time and there is increasing evidence of their greater extent in recent centuries. In some cases their direct effect on the underlying terrain appears to have been negligible or protective. This protective function is partly offset by the release of seasonal meltwater which causes marginal erosion, landslips and mass movements in saturated surface material. This paper presents observations resulting from a visit in 1963 to a small ice body of this type, "Tiger Ice Cap",* in northern Baffin Island at Lat. 71° 20′ N, Long. 78° 45′ W (Figures 1 and 2). In addition to the ground examination, a number of observations of this ice body and others in the vicinity were made from the air in 1962 and 1963. The recent history of the ice body was also studied from air photographs taken in 1949, 1958 and 1961. Laboratory investigation of botanical material obtained from the area in 1963 is being carried out by R. E. Beschel in the Department of Biology, Queen's University.

MS submitted September, 1965.

THE ICE BODY

Tiger Ice Cap is situated on a till-covered upland plateau of granitic and gneissic rocks at about 600 metres above sea level. In 1961 it

*The name "Tiger Ice Cap" is used here for convenience only. It has not been approved by the Canadian Permanent Committee on Geographical Names. No accepted generic term seems to exist for this type of ice body.

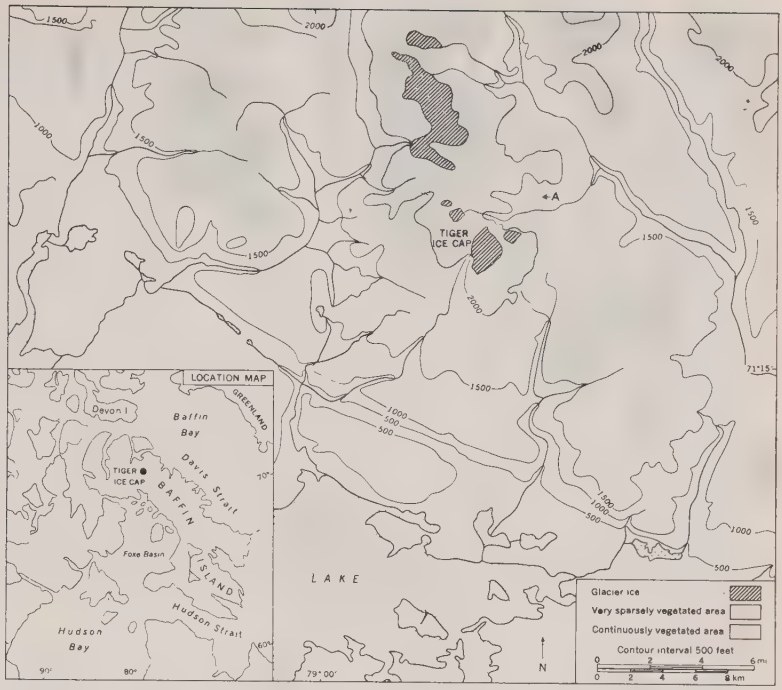

FIGURE 1
Generalized map showing very sparsely vegetated areas and ice caps.

measured about 3 km from north to south and about 1.9 km from east to west. Two smaller adjacent ice patches were once part of Tiger Ice Cap but have become detached by progressive melting. Altimeter measurements and an examination of the surrounding topography suggest that the maximum ice thickness is not more than 30 metres. Except in the few places where undercutting action of marginal streams has produced low ice cliffs up to 2.5 metres high, the ice margin is "feathered" and the ice surface has a gentle slope. On 19 August 1963, during a traverse across the ice body, the bulk of slushy snow remaining from the accumulation season was seen to be concentrated on the west and northwestern slopes rather than in the actual summit zone. There was a considerable amount of meltwater runoff on the surface and quantities of slush were being carried down to the margin in numerous meltwater runnels. No detailed examination of the ice was made in the summit zone (about 640 metres above sea level) but the surface layer consisted of 10 cm of water-saturated, loosely-bonded, white ice crystals from 2 to 5 cm in diameter. Below this there was much harder white to blue ice which was difficult to chop with an ice axe. Small excavations made in the loose surface layer filled immediately with meltwater. Cryoconite pitting occurred all over the surface; the holes contained very fine, presumably windblown, sediment. No debris that might have resulted from glacial erosion was seen anywhere on the ice surface.

From the air a distinct series of darker toned bands can be seen on Tiger Ice Cap and neighbouring ice bodies. In some cases these bands are parallel with the ice margins and may indicate regular seasonal accumulation concentrated in the summit zones. In other places one set of parallel bands may be overlain discordantly by another set suggesting changing centres of accumulation not necessarily in the highest parts. There are no crevasses and no other sign of ice motion was seen. The ice bodies appear to be the decaying remnants of extensive thin static ice sheets.

The previously greater extent of such ice bodies in the area has been suggested by Ives (1962). He estimated that possibly 70 per cent of the northern Baffin Island upland was thus ice-covered two to three hundred years ago, on the basis of the appearance of widespread lichen-free zones visible on aerial photographs. Estimates of the extent of specifically lichen-free zones are not easy to make in the vicinity

FIGURE 2. Tiger Ice Cap. 23 July 1961. Scale c. 1:36,000. National Air Photographic Library A17040-17.

FIGURE 3. Tiger Ice Cap. 8 August 1949. Scale c. 1:36,000. National Air Photographic Library T 365c-5.

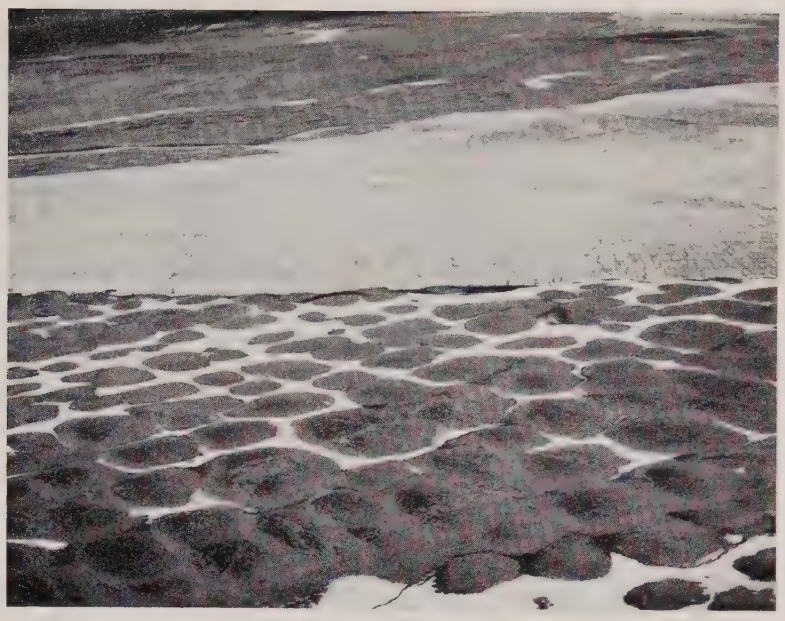

FIGURE 4
Oblique aerial view westward across southern part of Tiger Ice Cap. 17 August 1963. Dark-toned areas on the crests of the tundra polygons consist of the moss Polychritum.

of Tiger Ice Cap, as dark-toned zones on air photographs have proved to be mainly moss-covered areas or to consist of a surface skin of algae and other organic material to which the term "gloeoplacoid crust" has been applied by W. Weber (Beschel, 1963). Hence Figure 1, showing dark-toned zones appearing on air photographs of the Tiger Ice Cap area, indicates the extent of all types of near-continuous vegetation and not solely lichen cover.

Vertical air photographs taken on 23 July 1961, 1 September 1958 and 8 August 1949, together with ground observations and oblique air photographs made in 1962 and 1963 (Figures 2, 3 and 4), allow an estimate of the average rate of recession to be made (Falconer, 1962a). Between 1949 and 1963 the average rate of marginal recession was about 18 to 20 metres per year (Figure 5), and total recession of the margin varied between 150 and 450 metres depending on location. Parts of the ice body as it existed in 1949 have since become detached and are now separate small ice bodies to the northwest and east.

PATTERNED GROUND AND VEGETATION

The area exposed by recession displays well-preserved patterned ground features primarily in the form of large tundra polygons, some up to 50 metres in diameter (Figure 6). These features have raised centres, are bordered by well-defined fissures containing large boulders and are formed in coarse glacial till consisting mainly of sub-rounded granite and granite-gneiss boulders and cobbles in sandy gravel. The fissures are usually more than one metre in depth below the main surface of the polygons and in some cases hold both snow and flowing or stagnant water. In places fine material may have been removed from the fissures as they were progessively occupied by meltwater streams at the margin of the receding ice body. Smaller polygonal patterns are found on the raised surfaces of the larger polygons. At the actual glacier margin the tundra polygons can be seen emerging from beneath the melting ice edge. The higher centres of the polygons sometimes emerge first and form small isolated patches of exposed ground, whereas the polygon fissures remain ice-filled longer giving an uneven appearance to parts of the ice edge. No evidence of deformation or direct erosion of the polygons by moving ice could be found.

Near the ice body patches of vegetation, mainly composed of dead moss *(Polychritum juniperum),* occur in the centres of the polygons (Figure 7) and areas of dead polychritum mosses occur immediately adjacent to the ice edge and under small overhangs of ice in areas

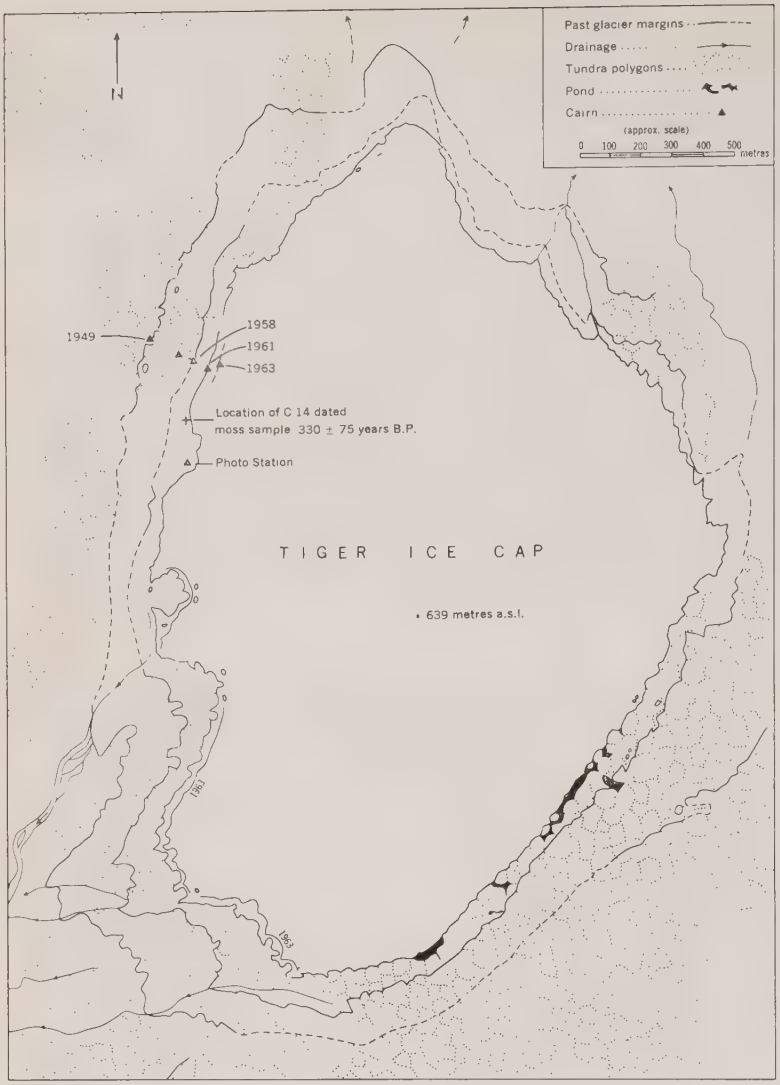

FIGURE 5
Recession of Tiger Ice Cap, 1949-1963.

exposed by melting during the year 1962-63. Outside the estimated position of the 1949 margin vigorous new moss shoots appear in places to be growing directly out of the underlying dead moss. This is perhaps due to the *in situ* germination of dormant spores, as the new growth is entirely concentrated on the "dead" moss mats. However, it is also possible that the dead moss mats provide the best conditions for the germination of migrant spores. There are no signs of alteration of the ground surface or vegetation by ice movement, only marginal meltwater erosion and resultant slumping having affected the terrain. In addition to the undisturbed emerging moss mats, various undamaged fruticose and crustose lichens can be seen on boulders very recently exposed by melting of the ice. Although there is by no means a continuous cover they are easy to find. The commonest species is *Rhizocarpon geographicum* with smaller numbers of *Alectoria pubescens* and *Alectoria miniscula* in addition to a few foliose species. Many lichen thalli appear fresh and indistinguishable from those commonly encountered elsewhere in the area and it cannot be safely assumed that they are dead. A number of lichen and moss samples were collected for

FIGURE 6
Fissure at the border of a tundra polygon near the edge of Tiger Ice Cap. 23 August 1963.

laboratory examination by R. E. Beschel and the results will be reported later. A number of reports have recently appeared of the finding of apparently living undamaged lichens and other vegetation, sometimes in association with undisturbed patterned ground immediately adjacent to glaciers, in some cases emerging from beneath the ice, or having been obtained by excavation through the ice to the glacier bed (Beschel, 1961; Schytt, 1961; Smith, 1961; Goldthwait, 1961 and Swinzow, 1962).

A sample of dead polychritum moss uncovered by recession of the Tiger Ice Cap margin between July 1961 and August 1963 has a radiocarbon age of 330 ± 75 years (I-1204), indicating that the moss may have been killed by the persistence of snow and ice cover in the area at about A.D. 1630. However, the build-up of the plateau ice cover may have begun before that date and probably continued afterwards as the various snowdrifts and ice patches coalesced. Inundation of existing vegetation by ice at that time is in agreement with glacier advances in west Greenland in the early seventeenth century (Weidick, 1963) and the estimated date of certain of the outer Lewis Glacier moraines of the Barnes Ice Cap some one hundred miles to the southeast (Andrews and Webber, 1964), and is in the same range as the date of 240 ± 100 years (B-464) reported by Müller (1964) for organic material overridden by an advance of the White Glacier on Axel Heiberg Island.

Five km north of Tiger Ice Cap an outcrop

FIGURE 7
Undisturbed mat of dead polychritum moss uncovered by recession of western margin of Tiger Ice Cap between 23 July 1961 and 20 August 1963. Note the gentle slope of the ice edge and marginal meltwater stream. 20 August 1963.

of banded magnetite forms a prominent hill about 70 metres above the plateau surface (A in Figure 1). Almost all the exposed rock surfaces of the summit zone are covered by a near-continuous growth of large crustose lichens, notably *R. geographicum,* terminating at a sharply defined trimline some 15 metres below the summit. Although the lichen growth rates for this locality are not yet determined, it may be assumed that conditions will be comparable with those found at the northern end of the Barnes Ice Cap where Andrews and Webber (1964) estimated a rate of 5.4 mm per century for *R. geographicum.* Using this rate, some of the larger lichens measured on the hilltop described here must be at least 1,000 years old. It therefore appears that the hilltop remained a nunatak zone for many hundreds of years and that consequently the recent ice cover on the plateau may never have been more than 50 to 70 metres thick.

ACKNOWLEDGMENTS

This paper is based on field work done as part of the Geographical Branch Baffin Island Project. Thanks are due to Dr. R. E. Beschel of Queen's University who arranged for radiocarbon dating of a vegetation sample. Enthusiastic logistical support from Baffinland Iron Mines Ltd. is gratefully acknowledged.

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NATIONAL ADVISORY COMMITTEE ON GEOGRAPHICAL RESEARCH: REPORT ON THE FIRST YEAR OF OPERATION

INTRODUCTION

The National Advisory Committee on Geographical Research was created on 14 April 1965 by Order in Council, P.C. 1965-693. Dr. F. Kenneth Hare was the first Canadian geographer to draw attention formally to the need for a national approach to geographical research. In his presidential address of 26 May 1964 to the Canadian Association of Geographers, Dr. Hare pointed out that a significant proportion of geographical research in Canada ought to be aimed directly at helping national development. He went on to urge the establishment of a group that would embrace as its objective a comprehensive national approach to the development of geography. The Geographical Branch, with the strong support of Dr. W. E. van Steenburgh, and the recommendation of a special advisory committee which met in Ottawa on 26 and 27 November 1964 under the chairmanship of the Branch Director, developed Dr. Hare's initiative. This resulted in the Minister of the Department moving the Order in Council in which objectives of the new committee were set as follows:

> "(a) assist in the co-ordination of geographical research in Canada,
> (b) promote the development of geographical research through the recommendation of grants-in-aid."

During the first year of its existence the Committee held three meetings, two in Ottawa and one in Sherbrooke, Quebec, to coincide with the annual meeting of the Canadian Association of Geographers. This short report is intended to give a brief summary of the work of the Committee during its first year.

MEMBERSHIP

Dr. L. Beauregard, Chairman, Institut de Géographie, Université de Montréal
Dr. J. W. Birch, Chairman, Geography Department, University of Toronto
Dr. E. Christiansen, Saskatchewan Research Council
Dr. J. G. Fyles, Pleistocene Section, Geological Survey of Canada
Dr. F. Grenier, Chairman, Institut de Géographie, Université Laval
Dr. J. D. Ives, Director, Geographical Branch
Dr. G. Jacobsen, Tower Construction Company, Montreal
Dr. T. Lloyd, Chairman, Geography Department, McGill University
Dr. J. R. Mackay, Geography Department, University of British Columbia
Mr. P. Marchant, British Newfoundland Corporation
Mr. M. K. Thomas, Climatological Section, Meteorological Branch, Department of Transport
Dr. K. W. Walter, Geographic Advisor, Imperial Oil Limited
Dr. T. Weir, Chairman, Geography Department, University of Manitoba
Dr. W. C. Wonders, Chairman, Geography Department, University of Alberta (Edmonton)

The Order in Council limits the membership to "not less than eleven and not more than nineteen." The decision to restrict the size of the initial Committee was taken to ensure the creation of a compact group and to permit some measure of freedom in membership rotation upon completion of the first three-year terms.

Mrs. Alexandra Cowie, Administrative Officer of the Geographical Branch and editor of

the Geographical Bulletin, was appointed Secretary of the Committee.

INAUGURAL MEETING, 5 NOVEMBER 1965

At the inaugural meeting the Assistant Deputy Minister of the Department of Mines and Technical Surveys, Dr. J. M. Harrison, welcomed the members and forecast an important role for the Advisory Committee to play in shaping departmental and national policy in geographical research. Dr. Harrison delivered the address of welcome on behalf of Dr. W. E. van Steenburgh, then Deputy Minister, who was unable to attend on account of illness.

The members agreed that the Committee should focus its attention on the drawing up of guidelines for the development of Canadian geographical research and to emphasizing areas of research that seemed to warrant special consideration. The Committee began its deliberations by turning its attention to the Geographical Branch.

Following Dr. Harrison's outline of changes in the Department of Mines and Technical Surveys attendant upon the creation of a new Water Research Branch, and a report on current research in the Geographical Branch given by Dr. Ives, the Committee discussed the development of geographical research in Canada and emphasized the vital part to be played by the Geographical Branch. Recommendations were made to the Minister of Mines and Technical Surveys to the effect that both physical geography and economic geography within the Branch be strengthened, rather than weakened by the departmental reorganization currently underway.

The second part of the meeting was devoted to the setting up of a grants sub-committee and the discussion of guidelines for the award of research grants from the sum of $25,000 provided in the Geographical Branch main estimates for 1966-67.

SECOND MEETING, 4 FEBRUARY 1966

At this meeting serious thought was given to the selection of specific areas of geographical research which, within the Committee's terms of reference, required urgent development on a national scale. The discussion resulted in the setting up of four working groups:

(a) *Working group on regional analysis*

This working group was charged with the important task of developing recommendations for the refinement of methods of regional analysis. It was contended that one of the vital roles the geographical profession could play in the development of Canada was the production of regional geographies as a basis for regional development and the full appraisal of regional resource potential. The particular need for examination of existing methods of analysis and their development was recognized.

Professor J. W. Birch was appointed chairman and asked to take the initiative of appointing members. It was hoped that a preliminary report could be presented to the Committee at its next meeting.

(b) *Working group on resource geography*

This working group was created to work in close liaison with the working group on regional analysis. Its first tasks would include a full survey of current work and the recommendation to the main Committee of specific areas of research requiring immediate attention.

The Committee agreed that Professor Ian Burton, of the Geography Department, University of Toronto, be asked to act as chairman and to appoint members. It was hoped that a preliminary report could be presented to the Committee at its next meeting.

(c) *Working group on remote sensing*

The technological revolution of post-war years, and particularly the development of high altitude and earth satellite sensing techniques, has opened up a series of new tools that greatly facilitate the collection of geographic data. It was felt imperative that a working group be set up to keep abreast of developments and to report to the main Committee on those having a direct bearing on geographical research.

The Committee agreed that Professor J. B. Bird, of the Geography Department, McGill University, be invited to act as chairman and to appoint members. An initial report was to be requested within a year.

(d) *Working group on statistical data*

The creation of this working group was a recognition of the great impact that recent developments in the processing of statistical data was having on all aspects of geographical research. The initial objectives emphasized included a survey of the existing literature and recommendations on further development.

This working group was established jointly with the Canadian Association of Geographers under the chairmanship of Professor R. Thoman of the Geography Department, Queen's University.

GRANTS IN AID OF RESEARCH

Immediately following the inaugural meeting, an invitation was extended to the geographical profession in Canada to submit applications for research support. An upper limit of $2,000 per grant was decided upon, and topics restricted to Canadian themes, because of the limited funds available in this first year of operations. Forty-three applications were received requesting a total of $75,000. The Committee reviewed and accepted the recommendations of the grants sub-committee that 23 grants, ranging from $200 to $2,000 and totalling $25,000, be awarded. The grants are listed in Appendix 1.

Liaison has been established with other grant-awarding agencies, such as the National Research Council and the Canada Council. It is hoped that the Committee's program will complement the work of these other organizations although great stress was placed on the ambiguous and difficult position in which the geographer frequently finds himself—that of falling between the physical sciences and the humanities.

In order to obtain information on which to base long range planning for funding the grants program, Dr. J. Lewis Robinson, Chairman of the Department of Geography, University of British Columbia, had been asked at the first meeting to collect information on research grants from all sources received by geography departments in recent years. He was also requested to estimate the total amount required to meet the needs of the next five years. Dr. Robinson gave his report at the second meeting. He pointed out that, because of the rapid expansion of the geography departments it would be necessary at least to double the total value of grants. He pointed out that the number of geographers on university faculties had doubled in the last four years and that this growth was forecast to accelerate. His report was duplicated for distribution to all chairmen of geography departments in Canada. The Committee expressed the hope that the initial sum of $25,000 could be significantly increased for the 1967-68 fiscal year; the Chairman agreed to make provision for as substantial an increase as possible in the main estimates of the Geographical Branch.

THIRD MEETING, 25 MAY 1966

The third meeting was primarily set up to receive initial preliminary reports from two working groups—(a) Resource Geography and (b) Regional Analysis—and to discuss the preparation of a report to be submitted to the Minister. A permanent Grants sub-committee was appointed and guidelines were laid down to facilitate the advertisement and awarding of research grants. The grants available for 1967-68 and the conditions of award are given in Appendix 2. Close liaison was established with the Canadian Association of Geographers and it was decided to explore the possibilities of co-operating with the Association to hold a symposium on regional analysis and resource geography.

A fourth meeting was scheduled for early 1967.

July 1966 (J. D. Ives, Chairman)

Appendix 1

Grants Awarded by National Advisory Committee on Geographical Research for 1966-67

Anderson, D. M. Geography Carleton	Patterns and problems of recreational land use in eastern Ontario	$ 500
Ashwell, I. Y. Geography Alberta	City climate of Calgary	$ 350
Beauregard, G. Géographie Montréal	Structure du centre des affaires de Montréal	$2,000
Boileau, G. Géographie Montréal	Géographie de la fonction commerciale de Montréal	$2,000
Brookes, I. A. Geography York	Geomorphological study of western Newfoundland	$1,250
Burghardt, A. F. Geography McMaster	The early development of road patterns in the Niagara Peninsula (c.1780-1850)	$ 300
Cazalis, P. Géographie Laval	Terminologie des paysages agraires	$1,000
Coulson, M. R. C. Geography Alberta	The evolution of federal electoral boundaries in Alberta	$ 550
Curry, L. Geography Toronto	Probabilistic analysis of the climatic elements	$2,000
Ford, D. C. Geography McMaster	Exploration and genetic studies of limestone caverns in the Cordillera of Canada	$2,000
Golledge, R. G. Geography British Columbia	An evaluation of super-market sites in Vancouver, B.C.	$1,000
Hamill, L. Geography Alberta	Identification and measurement of the recreational potential of the wildlands of southwest Alberta.	$ 500
Innes, F. C. Geography McGill	A study of the advance and retreat of rural settlement and occupation in the Rouge River Valley, Quebec.	$1,650
Mackay, J. R. Geography British Columbia	Movement of soil moisture in the active layer, above permafrost, Mackenzie Delta area, N.W.T.	$ 855
Manzagol, C. Géographie Montréal	Aspects et problèmes spatiaux de la croissance industrielle dans le Montréal métropolitain	$2,000
Mathews, W. H. Geology British Columbia	Behaviour and effects of creeping snow, Mount Seymour, B.C.	$ 700
Melton, M. A. Geography British Columbia	Energy budget of a small watershed in British Columbia —relationship to quantitative geomorphology.	$2,000
Minghi, J. V. Geography British Columbia	Study of a selected portion of the Canada-United States boundary.	$ 400
Racine, J.-B. Géographie Sherbrooke	Étude géographique d'une frange urbaine de Montréal: Pierrefonds ou St-Bruno	$2,000
Ritchot, G. Géographie Montréal	Étude de la géographie physique et humaine du Mont-Royal, à Montréal	$ 200
Ross, W. G. Geography Bishop's	American whaling in Hudson Bay	$ 500
Sim, V. W. Geography Western Ontario	Quantitative observations on the effects of fluvial and masswasting processes on the Lake Erie shore-bluff and in adjacent first and second order stream channels south of London, Ontario.	$ 800
Straw, A. Geography McMaster	Pleistocene geomorphology of the Bronte Creek drainage basin, north of Hamilton, Ontario.	$ 445

Appendix 2

GEOGRAPHY RESEARCH GRANTS

THE NATIONAL ADVISORY COMMITTEE ON GEOGRAPHICAL RESEARCH

Applications are invited from members of Canadian university faculties and research institutions for grants in aid of geographical research. Grants may be used for payment of assistants, purchase of equipment and materials, and travel and expenses related to specific research projects undertaken by individuals or small groups.

Grants may not be used for salary of an applicant, purchase of equipment normally considered to be the responsibility of applicant's institution, nor for preparation of textbooks or similar publications from which royalties would be expected.

As the funds available to the Committee are limited, it is anticipated that an upper limit of $3,000 per grant may need to be set. Since the Committee's objective is to provide support for as large a number as possible, applications for small amounts, including those for partial support, are particularly encouraged.

Conditions of Award

Decisions on applications are announced in February and grants normally paid in May. Grants are made available to the Committee by the Geographical Branch, Department of Mines and Technical Surveys, and are subject to appropriation of funds by Parliament.

Funds are administered through the business office of a grantee's institution. A statement of account as of 31 March, following year of award, and on request, is to be submitted to the Secretary of the Committee.

Grantees are required to submit to the Secretary a progress report by 31 December of the year of award, and/or on request, and a final report. A copy of any publications arising from the proposed research is also to be submitted to the Secretary. All publications should carry acknowledgment of the assistance received.

Equipment purchased under a grant becomes the property of the institution where the grant is held, but is for the use of the applicant until completion of the project.

Applications

Application forms may be obtained from university geography departments or from:

The Secretary,

National Advisory Committee on Geographical Research

c/o Geographical Branch

601 Booth Street

Ottawa 4, Ontario.

Deadline for receipt of applications is 31 December.

GEOGRAPHICAL BULLETIN, VOL. 8, NO. 2, PP. 206–210, 1966

COMITÉ CONSULTATIF NATIONAL DE LA RECHERCHE GÉOGRAPHIQUE
RAPPORT DE LA PREMIÈRE ANNÉE D'ACTIVITÉ

INTRODUCTION

Le Comité consultatif national de la recherche géographique a été créé le 14 avril 1965 par décret du conseil C.P. 1965-693. M. F. Kenneth Hare a été le premier géographe canadien à signaler la nécessité d'envisager la recherche géographique du point de vue national. Dans son discours présidentiel devant l'Association canadienne des géographes, le 26 mai 1964, il a fait ressortir qu'une partie importante de la recherche géographique au Canada devrait servir directement à favoriser le développement du pays. Il a fortement recommandé la formation d'un groupe qui aurait pour but de coordonner les recherches géographiques sur le plan national. La Direction de la géographie, forte de l'appui de M. W. E. van Steenburgh et de la recommandation d'un comité consultatif spécial qui s'est réuni à Ottawa les 26 et 27 novembre 1964 sous la présidence du directeur, a donné suite à la proposition de M. Hare. C'est ainsi que le ministre s'est fait le parrain du décret du conseil qui définissait en ces termes les objectifs du nouveau Comité:

«a) aider à la coordination de la recherche géographique au Canada;
b) encourager l'avancement de la recherche géographique en recommandant certaines subventions.»

Au cours de sa première année d'existence, le Comité s'est rencontré à trois reprises, deux fois à Ottawa et une fois à Sherbrooke (Québec) à l'occasion de la réunion annuelle de l'Association canadienne des géographes. Le présent rapport donne un bref aperçu du travail accompli par le Comité au cours de sa première année d'existence.

MEMBRES

M. L. Beauregard, président, Institut de géographie, Université de Montréal
M. J. W. Birch, président, Département de géographie, Université de Toronto
M. E. Christiansen, Conseil des recherches de la Saskatchewan
M. J. G. Fyles, Section du Pléistocène, Commission géologique du Canada
M. F. Grenier, président, Institut de géographie, Université Laval
M. J. D. Ives, directeur, Direction de la géographie
M. G. Jacobsen, Tower Construction Company, Montréal
M. T. Lloyd, président, Département de géographie, Université McGill
M. J. R. Mackay, Département de géographie, Université de la Colombie-Britannique
M. P. Marchant, British Newfoundland Corporation
M. M. K. Thomas, Section de climatologie, Direction de la météorologie, ministère des Transports
M. K. W. Walter, conseiller en géographie, Imperial Oil Limited
M. T. Weir, président, Département de géographie, Université du Manitoba
M. W. C. Wonders, président, Département de géographie, Université de l'Alberta (Edmonton)

Le décret du conseil stipule que le nombre des membres «ne devra pas être inférieur à onze ni dépasser dix-neuf». La décision de limiter ainsi le nombre des membres du Comité initial a été prise pour assurer la formation d'un groupe compact et pour laisser une certaine liberté dans le remplacement des membres après la première période de trois ans.

M[me] Alexandra Cowie, agent d'administration à la Direction de la géographie et rédactrice du *Geographical Bulletin* a été nommée secrétaire du Comité.

SÉANCE D'INAUGURATION, LE 5 NOVEMBRE 1965

A la séance d'inauguration, le sous-ministre adjoint du ministère des Mines et des Relevés techniques, M. J. M. Harrison, a souhaité la bienvenue aux membres et a prédit que le Comité consultatif jouera un rôle important dans l'élaboration d'une ligne de conduite pour les recherches géographiques, tant au ministère qu'à l'échelle nationale. M. Harrison a prononcé le discours de bienvenue au nom de M. W. E. van Steenburgh, sous-ministre, qui ne pouvait assister à la réunion pour cause de maladie.

Les membres ont convenu que le Comité doit formuler des directives pour l'expansion de la recherche géographique au Canada, et de mettre l'accent sur les domaines de la recherche qui semblent mériter une attention particulière. Le Comité s'est intéressé tout d'abord au programme de la Direction de la géographie.

Après que M. Harrison eut exposé les changements survenus au ministère des Mines et des Relevés techniques par suite de la création de la nouvelle Direction de l'hydrologie, et que M. Ives eut donné un compte rendu des recherches en cours à la Direction de la géographie, le Comité a étudié la question du développement général de la recherche géographique au Canada et souligné le rôle important que doit y jouer la Direction. Il a recommandé au ministre des Mines et des Relevés techniques de renforcer les domaines de la géographie, tant physique qu'économique, au sein de la Direction plutôt que de les affaiblir par la réorganisation en cours.

La deuxième partie de la séance a été consacrée à la mise sur pied d'un sous-comité des subventions et à l'étude des conditions de l'octroi de celles-ci à même la somme de $25,000 prévue dans le budget principal de la Direction de la géographie pour 1966-1967.

DEUXIÈME SÉANCE, LE 4 FÉVRIER 1966

Au cours de cette séance, on s'est occupé de choisir les domaines de recherche géographique qui, selon le mandat du Comité, doivent être développés au plus tôt à l'échelle nationale, discussion qui a mené à la formation de quatre groupes d'étude:

a) *Le groupe d'étude de l'analyse régionale*

Ce groupe d'étude a eu pour tâche importante de recommander le perfectionnement des méthodes d'analyse régionale. On a reconnu que l'un des rôles essentiels que les géographes peuvent jouer dans l'évolution du pays est de publier des «géographies régionales» qui serviraient de fondement à l'inventaire et à la mise en valeur des richesses régionales. On a reconnu la nécessité de reviser et d'améliorer les méthodes d'analyse existantes.

Le professeur J. W. Birch a été nommé président du groupe et on lui a demandé de choisir personnellement ses adjoints. On a exprimé le vœu qu'un rapport préliminaire soit présenté au Comité lors de la prochaine réunion.

b) *Le groupe d'étude de la géographie des ressources*

Ce groupe d'étude a été formé pour travailler en collaboration étroite avec le précédent. Sa première tâche consiste à faire un relevé complet des travaux en cours et à soumettre au Comité des recommandations sur les principaux domaines de recherche qui exigent une attention immédiate.

Le Comité s'est mis d'accord pour demander au professeur Ian Burton, du Département de géographie de l'Université de Toronto, d'accepter la présidence de ce groupe et de s'adjoindre des membres. On a formulé le vœu qu'un rapport préliminaire soit présenté au Comité lors de la prochaine réunion.

c) *Le groupe d'étude des téléobservations*

La révolution technologique de l'après-guerre, surtout l'avènement des procédés d'observation par satellite et par vol à haute altitude, a fourni une série de nouveaux outils qui facilitent grandement la tâche de recueillir les données géographiques. On a cru nécessaire de former un groupe d'étude ayant pour tâche de suivre l'évolution dans ce domaine et de signaler au Comité principal tout ce qui se rapporte directement à la recherche géographique.

Le Comité a décidé de demander au professeur J. B. Bird, du Département de géographie de l'Université McGill, d'accepter la présidence du groupe et d'en nommer les membres. On lui a demandé de soumettre un premier rapport d'ici un an.

d) *Le groupe d'étude des données statistiques*

En créant ce groupe, le conseil reconnaît la grande influence des progrès récents dans le traitement des données statistiques sur tous les aspects de la recherche géographique. On a insisté sur la nécessité d'inventorier les publications existantes à ce sujet et de formuler des recommandations sur les progrès en cours.

Ce groupe a été formé en collaboration avec l'Association canadienne des géographes, sous la présidence du professeur R. Thoman, du Département de géographie de l'Université Queen's.

SUBVENTIONS A LA RECHERCHE

Immédiatement après la séance d'inauguration, les géographes canadiens ont été invités à présenter des demandes de subventions. Le montant maximum des subventions a été fixé à $2,000 et les sujets limités à des thèmes canadiens du fait des fonds restreints dont on disposait pour la première année. Le Comité a reçu quarante-trois demandes représentant un total de $75,000. Après en avoir fait l'étude, il a accepté la recommandation du sous-comité d'accorder vingt-trois subventions allant de $200 à $2,000, pour un total de $25,000. On en trouvera la liste à l'annexe 1.

Le Comité s'est mis en contact avec d'autres organismes qui accordent des subventions, notamment le Conseil national de recherches et le Conseil des arts du Canada. On espère que son programme pourra compléter le travail de ces autres organismes bien qu'on ait exposé la situation difficile et ambiguë où se trouve le géographe, c'est-à-dire entre les sciences physiques et les humanités.

Pour obtenir des renseignements utiles à l'élaboration à long terme du programme de subventions, on a demandé lors de la première réunion à M. J. Lewis Robinson, président du Département de géographie de l'Université de la Colombie-Britannique, de se renseigner au sujet de toutes les subventions à la recherche accordées aux départements de géographie au cours des dernières années. On lui a aussi demandé d'estimer pour les cinq prochaines années les sommes nécessaires pour subvenir aux besoins. M. Robinson a présenté son rapport à la deuxième séance. Il a signalé qu'il faudrait au moins doubler le montant total accordé en subventions de toutes sources à cause de l'expansion rapide des départements de géographie. Il a noté en outre que le nombre des géographes dans les facultés a doublé au cours des quatre dernières années et l'on prévoit que cet accroissement va s'accélérer. On a fait polycopier le rapport pour le distribuer à tous les chefs des départements de géographie au Canada. Le Comité a exprimé l'espoir que la somme initiale de $25,000 pourra être augmentée sensiblement pour l'année financière 1967-1968. Le président a consenti à prévoir une augmentation aussi forte que possible dans le budget principal de la Direction de la géographie.

TROISIÈME SÉANCE, LE 25 MAI 1966

La troisième réunion a été convoquée en premier lieu pour prendre connaissance des rapports préliminaires de deux groupes d'étude, soit le groupe de l'analyse régionale et le groupe de la géographie des ressources, et pour étudier la préparation d'un rapport à présenter au ministre. On a mis sur pied un sous-comité permanent des subventions et établi des directives générales en vue de faciliter la publication de l'annonce des subventions et d'aider le Comité à les accorder. Les subventions disponibles pour 1967-1968 et les conditions exigées paraissent à l'annexe 2. Le Comité a établi des relations étroites avec l'Association canadienne des géographes et décidé de proposer à celle-ci la tenue d'un symposium conjoint sur l'analyse régionale et la géographie des ressources.

La quatrième séance est prévue pour le début de 1967.

Juillet 1966

(J. D. Ives, président)

Annexe 1

Subventions accordées par le Comité consultatif national de la recherche géographique 1966-1967

Anderson, D. M. Geography Carleton	Patterns and problems of recreational land use in eastern Ontario	$ 500
Ashwell, I. Y. Geography Alberta	City climate of Calgary	$ 350
Beauregard, G. Géographie Montréal	Structure du centre des affaires de Montréal	$2,000
Boileau, G. Géographie Montréal	Géographie de la fonction commerciale de Montréal	$2,000
Brookes, I. A. Geography York	Geomorphological study of western Newfoundland	$1,250
Burghardt, A. F. Geography McMaster	The early development of road patterns in the Niagara Peninsula (c.1780-1850)	$ 300
Cazalis, P. Géographie Laval	Terminologie des paysages agraires	$1,000
Coulson, M. R. C. Geography Alberta	The evolution of federal electoral boundaries in Alberta	$ 550
Curry, L. Geography Toronto	Probabilistic analysis of the climatic elements	$2,000
Ford, D. C. Geography McMaster	Exploration and genetic studies of limestone caverns in the Cordillera of Canada	$2,000
Golledge, R. G. Geography British Columbia	An evaluation of super-market sites in Vancouver, B.C.	$1,000
Hamill, L. Geography Alberta	Identification and measurement of the recreational potential of the wildlands of southwest Alberta.	$ 500
Innes, F. C. Geography McGill	A study of the advance and retreat of rural settlement and occupation in the Rouge River Valley, Quebec.	$1,650
Mackay, J. R. Geography British Columbia	Movement of soil moisture in the active layer, above permafrost, Mackenzie Delta area, N.W.T.	$ 855
Manzagol, C. Géographie Montréal	Aspects et problèmes spatiaux de la croissance industrielle dans le Montréal métropolitain	$2,000
Mathews, W. H. Geology British Columbia	Behaviour and effects of creeping snow, Mount Seymour, B.C.	$ 700
Melton, M. A. Geography British Columbia	Energy budget of a small watershed in British Columbia —relationship to quantitative geomorphology.	$2,000
Minghi, J. V. Geography British Columbia	Study of a selected portion of the Canada-United States boundary.	$ 400
Racine, J.-B. Géographie Sherbrooke	Étude géographique d'une frange urbaine de Montréal: Pierrefonds ou St-Bruno	$2,000
Ritchot, G. Géographie Montréal	Étude de la géographie physique et humaine du Mont-Royal, à Montréal	$ 200
Ross, W. G. Geography Bishop's	American whaling in Hudson Bay	$ 500
Sim, V. W. Geography Western Ontario	Quantitative observations on the effects of fluvial and masswasting processes on the Lake Erie shore-bluff and in adjacent first and second order stream channels south of London, Ontario.	$ 800
Straw, A. Geography McMaster	Pleistocene geomorphology of the Bronte Creek drainage basin, north of Hamilton, Ontario.	$ 445

Annexe 2

SUBVENTIONS A LA RECHERCHE EN GÉOGRAPHIE

COMITÉ CONSULTATIF NATIONAL DE LA RECHERCHE GÉOGRAPHIQUE

Les membres des facultés d'universités canadiennes et d'institutions de recherche sont invités à présenter leurs demandes de subventions en vue de les aider à poursuivre des recherches en géographie. Les subventions pourront servir à payer des adjoints, à acheter de l'équipement et du matériel, et à payer les frais de déplacement et autres dépenses relatives à des projets spéciaux de recherche entrepris par des particuliers ou des petits groupes.

Les subventions ne pourront servir ni au paiement d'un salaire au candidat, ni à l'achat d'équipement habituellement fourni par l'institution, ni à la préparation de manuels ou de publications pouvant devenir la source de redevances.

Vu la modicité des fonds dont dispose le Comité, celui-ci devra probablement fixer un montant maximum de $3,000 pour chaque subvention. Cependant, comme il vise à venir en aide au plus grand nombre de personnes possible, le Comité encourage surtout les demandes de petites sommes, y compris celles d'aide partielle.

Conditions d'octroi

On fait connaître en février les décisions prises au sujet des demandes et les subventions sont habituellement versées en mai. Les fonds affectés aux subventions sont mis à la disposition du Comité par la Direction de la géographie, du ministère des Mines et des Relevés techniques, et ils font l'objet d'un vote de crédits au Parlement.

L'administration des fonds est confiée au trésorier de l'institution du requérant. Le trésorier doit faire parvenir un bilan financier au secrétaire du Comité le 31 mars de l'année qui suit celle de l'octroi, de même que sur demande.

Les bénéficiaires de subventions doivent présenter au secrétaire un rapport des progrès de leurs études avant le 31 décembre de l'année d'octroi, de même que sur demande. Ils doivent aussi faire parvenir un rapport définitif. Un exemplaire de toute publication résultant de la recherche projetée devra également être remis au secrétaire. Toutes les publications doivent faire mention de l'aide reçue.

L'équipement acheté à l'aide d'une subvention devient la propriété de l'institution où le bénéficiaire exerce, mais lui seul peut s'en servir pour la durée de ses travaux.

Demandes

On peut se procurer des formules de demande dans les départements de géographie des universités ou en s'adressant au:

Secrétaire,

Comité consultatif national de la recherche géographique,

Direction de la géographie,

601, rue Booth,

Ottawa 4 (Ont.).

Les intéressés doivent s'inscrire au plus tard le 31 décembre.

GEOGRAPHICAL BULLETIN, VOL. 8, NO. 2, PP. 211–215, 1966

BOOK REVIEWS

MARKET POTENTIAL AND ECONOMIC SHADOW. D. Michael Ray, Department of Geography, University of Chicago, Res. Paper 101, 164 p. Price $4.00

As the title implies, Dr. Ray's book is an attempt to broaden our knowledge of the factors governing the location of industry by combining the much discussed concept of market potential with his newly created hypothesis of economic shadow. Ray feels that in Ontario, market potential is the major determinant in the location of locally-controlled firms, and that economic shadow is the major control over the location of externally financed branch plants.

The dichotomous nature of the location of manufacturing in Ontario became apparent to the author while examining a residual plot of the equation:

$$X_1 = aX_2^{b_2}$$

where X_1 = a measure of manufacturing activity
X_2 = a measure of market potential

He noticed that the model, which "explained" seventy-five per cent of the spacial variation in manufacturing activity, tended to give systematic underpredictions for southwestern Ontario, and overpredictions for eastern Ontario. This, along with the knowledge that firms controlled from the United States provide almost one-third of the manufacturing employment in Ontario, led him to the conclusion that any attempt to explain industrial location in Ontario must treat locally controlled and externally controlled firms as two separate entities, each having its own locational philosophy.

The market potential portion of the model is a fairly straightforward modification of that introduced by Harris (1954) and later applied to Ontario by Kerr and Spelt (1960). Unlike Harris, who assumed a progressive distance decay proportional to transport costs, Ray uses an exponential function of distance, measured in miles, and unlike Kerr and Spelt, who used wholesale sales as a measure of the strength of the market, Ray uses retail sales.

The economic shadow segment of Ray's model is slightly more complicated. He feels that economic shadow is composed of three elements, each of which reflects the pattern of branch plant location in Ontario. The first element, sectoral affinity, hypothesises that branch plants will locate in an area between the primary market centre (Toronto) and the home office in the United States. In other words, the primary market centre will rarely constitute an intervening opportunity between the branch plant and the home office.

The second element, sectoral penetration, hypothesises that there is a direct relationship between the distance from the international boundary of the branch plant and the home office, or that the distance a company will penetrate into the chosen sector is directly proportional to the distance travelled to reach the point of entry. This concept is not new, but has been observed by Wolfe (1951) in his work on recreational travel. Wolfe found that the farther American tourists had to travel to reach the international boundary, the farther they would penetrate into Ontario for the purposes of recreation.

The third element of economic shadow, interactance decay, states that the number of branch plants located in an Ontario region by firms from a city in the United States, is directly proportional to the industrial growth in the American city, and inversely proportional to the straight line distance between the city and the Ontario region. Interactance decay partly accounts for the lack of industry in the eastern Ontario region because Toronto is an intervening opportunity between eastern Ontario and all other industrial areas in the United States, with the exception of the slowly growing industrial centres of New England.

After testing to ensure that market potential and economic shadow are not measures of the

same thing but are in fact orthogonal, Ray combines them to form a dual interactance model:

$$Y_i = a + b_1 \log \left[\sum_j \frac{M_j}{d_{ij}^{1.42}} \right] + b_2 \log \left[\sum_k \frac{.63 A_{ik} \cdot I_k^{.80}}{d_{ik}^{.85}} \right]$$

where: Y_i = Amount of manufacturing at point "P_i"

M_j = Retail sales at Canadian market "j"

d_{ij} = Road distance from "P_i" to market "j"

A_{ik} = A binary measure of sectoral affinity between United States city "k" and "P_i"

I_k = Number of plants at United States city "k"

d_{ik} = Air distance from city "k" to "P_i"

The results of multiple regression analysis show a coefficient of correlation of .91 when Y_i represented the number of industrial plants at point P_i, and .84 when Y_i was given the value of manufacturing employment. Examination of the residuals from regression suggests that the regional bias, present in the market potential plot, has been largely removed. Ray concludes that economic shadow contributes to the pattern of manufacturing activity in southern Ontario, and partly explains the regional contrast between the southwestern and eastern portions of the province.

Although Ray's dual interactance model "explains" only six per cent more of the spacial variation in the location of manufacturing than the straight market potential model, it is an important contribution to the literature because it represents the first time that anyone has attempted to study the location of manufacturing in Ontario as a dichotomous situation. It also represents the first attempt by a geographer to show the relationship between externally controlled branch plants and the international boundary.

A minor criticism that can be levelled at the author is that he has not gone far enough. His approach is in the spirit of much of the present work emanating from some members of the school of quantitative geographers in that it is general and takes an aggregative view of industry. One can sense a hiatus here between the method and the problem. The method is of the kind that has been successfully applied to broad aggregative situations in an attempt to develop theoretical models rapidly and so build up a body of theory which is known to be lacking. It may be questioned, however, whether the relationship between the economy of southern Ontario and neighbouring parts of the United States has any general or theoretical interest. It is a unique case and no general notions derived from its scrutiny are likely to be applicable elsewhere. Once this is recognized further deficiencies become apparent.

Seriously lacking in this work are discussions of the effect of the availability of such resources as raw materials, labour, capital and transportation facilities on the location of manufacturing. Similarly, how can one attempt to explain the contrasts in the location of manufacturing in eastern and southwestern Ontario without a discussion of the special problems of location in a remote area of the Canadian Shield?

A further criticism of Ray's work is that he has treated all branch plants, be they chemical companies or cheese factories, in the same manner. United States ownership in Ontario tends to predominate in the manufacture of automobiles, rubber, chemicals and electrical appliances. A thorough study of the types of externally controlled industry present in Ontario, and their importance within the American cities in the sample, would increase the power of the interactance decay portion of the model.

If it is a characteristic of a good book that it poses more questions than it answers, then *Market Potential and Economic Shadow* is a good book. Ray has answered some questions on the factors which govern the location of branch plants in Ontario, but has left many more unanswered ones in his wake. He has opened up a whole new area for future research, an area which will provide an excellent proving ground for the geographer equipped with the new tools of the trade. One can see applications for simulation of diffusion, linear programming, systems analysis and a host of other techniques, as one leafs through the pages of this book. Ray has provided an excellent beginning.

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(William H. Bell)

THE INSTITUTE OF BRITISH GEOGRAPHERS, TRANSACTIONS AND PAPERS NO. 35. George Philip and Son, Ltd., London, December 1964. 148 p. Price 35 shillings.

One of the most notable features in the post-war expansion of geographical activities in Britain has been the consolidation and growth of the Institute of British Geographers. With a mainly professional membership now approaching 1,000 in number, the Institute will shortly establish a permanent headquarters at 1 Kensington Gore, London S.W. 7, and also proposes to diversify its range of publications.

The traditional journal of the Institute, its *Transactions*, has recently become a semiannual publication, and no. 35 is the subject of this review. It contains ten research papers on a variety of topics. The established strength of British geography in geomorphology is represented by three papers. Climatology, which has been less well represented in the past, and economic geography form the subject of two papers apiece and there is one paper in each of the fields of hydrology, historical geography and the history of discovery. All the topics except two concern localities in Britain, and the authors come from eight British universities.

S. B. McCann writes on the raised beaches of Northeast Islay and Western Jura, in Scotland, where the 100-foot interglacial marine platform that was originally designated by W. B. Wright as "preglacial" is located. In a careful examination of the drift deposits, McCann distinguishes the interglacial surface with its traces of ice moulding and boulder clay from the superjacent late-glacial raised beach which is itself partially covered at the back by younger moraine and head. He also traces the fresh landforms of the postglacial 25-foot raised beach including caves, stacks and natural arches, and describes the suites of shingle ridges which on Jura occupy all levels between the clear upper and lower beaches, without providing any definite evidence of the intermediate stillstand recognizable elsewhere in western Scotland.

C. Embleton deals with erosion surfaces on both sides of the Menai Straits. This is a re-examination of earlier descriptive work by E. Greenly and H. Dewey in the light of recent advances in denudation chronology, and with the help of systematic morphological mapping. A marine origin is postulated for all the erosion flats present, which occur at all levels below 690 feet above sea level with fairly marked concentrations at nine levels below 530 feet.

B. W. Sparks and R. G. West present a detailed account of drift landforms around Holt in Norfolk. These are interpreted as constructional forms of a retreat stage of the Gipping glaciation and include two successive outwash plains, over 100 kames and kame terraces, and the Blakeney "esker", which is believed to be a crevasse filling.

J. Oliver presents a study of the upland temperatures and humidities of South Wales. Despite the intensity of the network of climatological stations in the British Isles, very few are located at high elevations. Oliver therefore set up and ran for sample periods two stations, one at 2,012 feet on an upland plateau and another at 1,225 feet in an incised high level valley. The records confirm the sparsely documented tendency for the upland temperature lapse in Britain to be greater than is normal. They also reveal that temperature regime combined with exposure provides the climatic limitations to pasture growth and forestry, whereas lack of moisture is rarely responsible for checks to plant growth.

E. C. Barrett describes local variations in rainfall trends in the Manchester region. There is ample evidence on a national scale, and on the basis of widely separated stations, that Britain's rainfall has tended to increase during the first half of the twentieth century. Barrett now directs attention to local trends, which can be significantly greater than those of more extensive areas. The Manchester region is quite typical of Britain in respect to most climatic elements but rainfall is an exception. Manchester coincides with an axis of high rainfall variability, which shades off to greater reliability both eastward into the Pennines and westward across the plain. A comparison of the mean

annual rainfall of the period 1890 to 1924 with that of 1925 to 1959 reveals that this axis is roughly reflected in, and perhaps explained by, an anomalous rainfall increase of over 15 per cent, which rapidly declines to nil towards the east, south and west and still farther out is transformed into a rainfall decrease. The possibility is explored that increasing urbanization may have modified local atmospheric conditions in such a way as to have precipitated more rainfall over the city and subtracted it from the outer zone.

D. C. Ledger's paper on hydrological characteristics of West African rivers is a first attempt to divide the area into water regions, and is based on regional differences of river regime. Seasonal changes of river beds, mean daily and monthly discharges, and flood characteristics are discussed together with the background of climatic statistics. The cartographic presentation of results suggests permissible interpolations and hence facilitates assessment of general problems and possibilities in those areas where hydrographic information is still very sparse.

M. Chisholm's paper on the classification and use of farming-type regions is critical of what geographers have so far achieved in this field. The author suggests a more dynamic approach in terms of active trends rather than static correlations and also advocates a closer liaison with agricultural economists.

D. C. D. Pocock's account of the development of the Frodingham ironstone field is basically factual and is justified by the current importance of this ore field which has an annual output of 5½ million tons, and supplies one third of Britain's total production of iron ore by weight.

"The Common Lands of Berkshire" by G. Whittington is a detailed county study deriving its inspiration from the report of the Royal Commission on Common Land published in 1958. Berkshire has an unusually low proportion of common land, constituting only 1.07 per cent of its area, which is related partly to the fact that it has little poor soil that remained unattractive to the enclosers. The date of enclosure is a second significant factor, as in those parishes which enclosed late, it was often, but not invariably, realized that provision of common land would alleviate the hardships of the poor and keep the poor rate down.

Finally, the paper by A. Davies on Prince Henry the Navigator is a fascinating reappraisal of Henry's contribution to the fifteenth century wave of geographic exploration and discovery. Certain contradictory facts in the records are construed to indicate that Henry's interest in exploration was greatly exaggerated by the royal chronicler Azurara in order to gain for the Royal House of Portugal the monopoly of discovery, conquest and trade in Africa granted in the papal bull of 1454. This monopoly was not used for further exploration, but for a very profitable trade in slaves, gold and pepper. The bias of Azurara's account is supported by the fact that it neglects Henry's true claims to greatness as a crusader against Islam and as an imperial strategist. It is contended that these activities were far more instrumental in promoting the resurgence of Europe than were his overrated feats of armchair navigation.

(Alice Coleman)

UNIVERSITY OF COLORADO STUDIES. NO. 3 IN EARTH SCIENCES, MAN AND THE EARTH. University of Colorado Press, Boulder, 1965. 112 p. Price $3.50.

A series of academic studies in many disciplines, e.g., anthropology, biology, economics, history, etc., has been published for many years by the University of Colorado Press. Although some of these studies were discontinued in the 1940's, for the past fifteen years a revised series has been issued. No. 3 in the Earth Sciences series is a special issue in honour of Dr. Harold A. Hoffmeister, former head of the department of geography at the University of Colorado. A brief statement of Dr. Hoffmeister's academic career of more than forty years at Colorado constitutes an introduction to the book.

The text is made up of two long articles and five shorter ones, all written by former University of Colorado geography students, who now hold academic posts. The first article by Erich Isaac on "Religious Geography and the Geography of Religion" has many interesting comments and concepts on a topic with which geographers do not seem to have been concerned. The second article by Melvin Marcus on "Summer Temperature Relationships in the St.

Elias Mountains" will be of direct interest to Canadian physical geographers; it describes the field work and methodology of arranging a series of meteorological readings during the summer of 1964 along a transect of the St. Elias Mountains in the Yukon and Alaska for purposes of glaciological and meteorological research as part of the Icefield Ranges Research Project.

Of the five shorter articles, one of interest to Canadian readers is that by Richard Thoman of Queen's University on "Internal Areas of Economic Stress: Some Canadian Approaches". The purpose of the article seems mainly to inform an American audience of developments taking place in Canada, and therefore there is little that will be new to Canadian economic geographers. Thoman describes the program and plans of ARDA (Agricultural Rehabilitation and Development Act) as related to areas of "underdeveloped" agriculture in Canada, and briefly mentions the Atlantic Development Board. He gives a little more space to the Area Development Agency, and discusses principles of "growth points" and "growth zones" in Canada. One could be critical of this jargon since it appears on a map which is nothing more than a map of all Canadian cities with 60-mile radius circles around them.

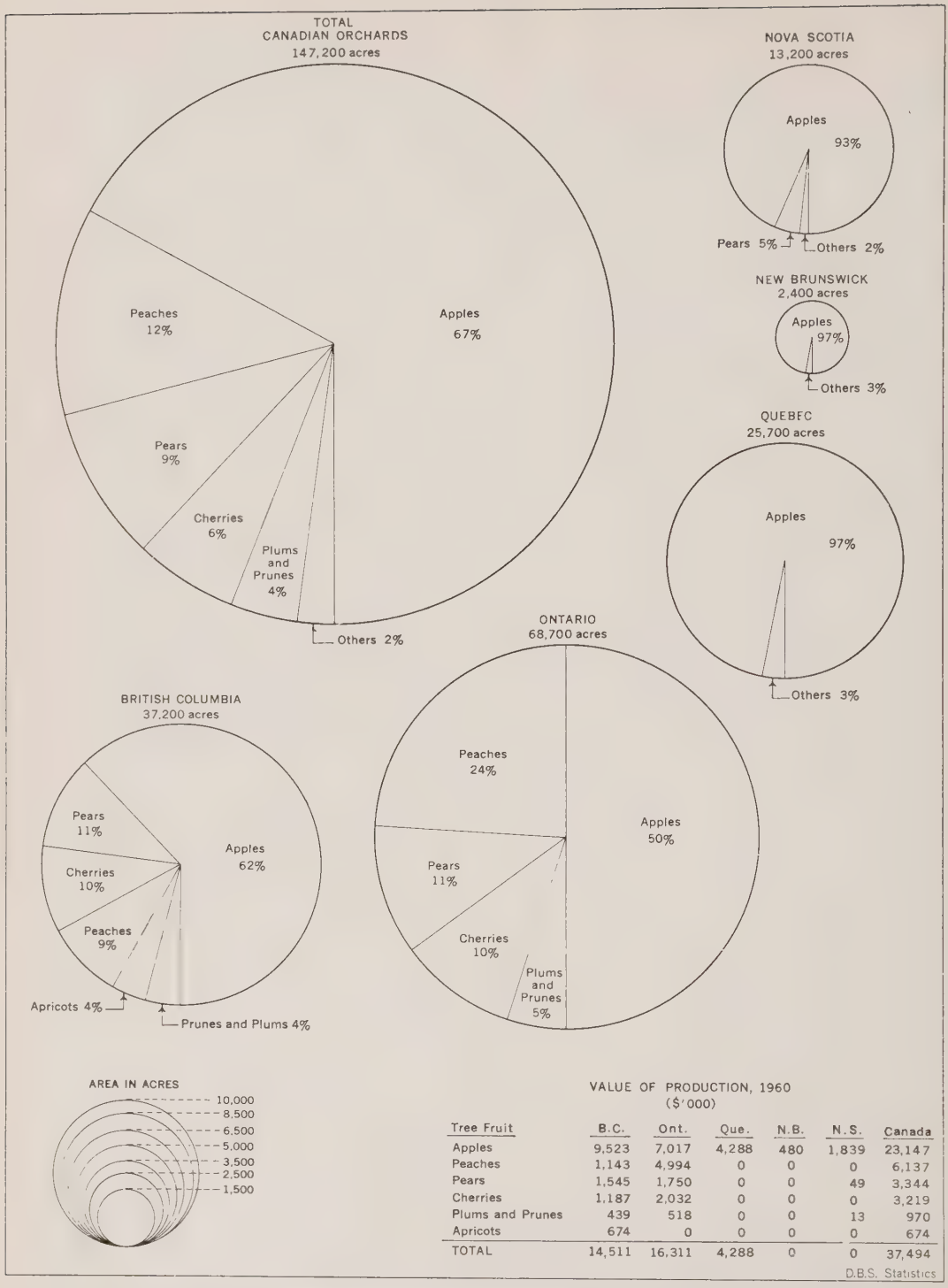
Of the remaining articles, one deals with "Mexico—Regional Planning in the Costera Region", and two are concerned with livestock in the American Southwest. A topic not often handled in the urban geography literature is the subject of the contribution of John Thompson of Syracuse University on "Geography of the Tertiary Sector: the Case of New York State". Cartographically-good maps illustrate all of the articles, and are of particular interest in the article on New York State.

(J. Lewis Robinson)

ERRATA

Corrected figures for "*The Geography of the Orchard Industry of Canada*", vol. 7, no. 1, by Ralph R. Krueger.

The following figures are corrections that the Errata in vol. 7, no. 2, p. 160, stated would appear in a future issue of the *Geographical Bulletin*. No change in the text of the original article is required in referring to the corrected Figures 6 and 7. Figure 1A, however, is new. It is the map referred to as Figure 2 on page 29, second column and as Figure 1 on page 30, first column. The other references to figures remain unchanged.



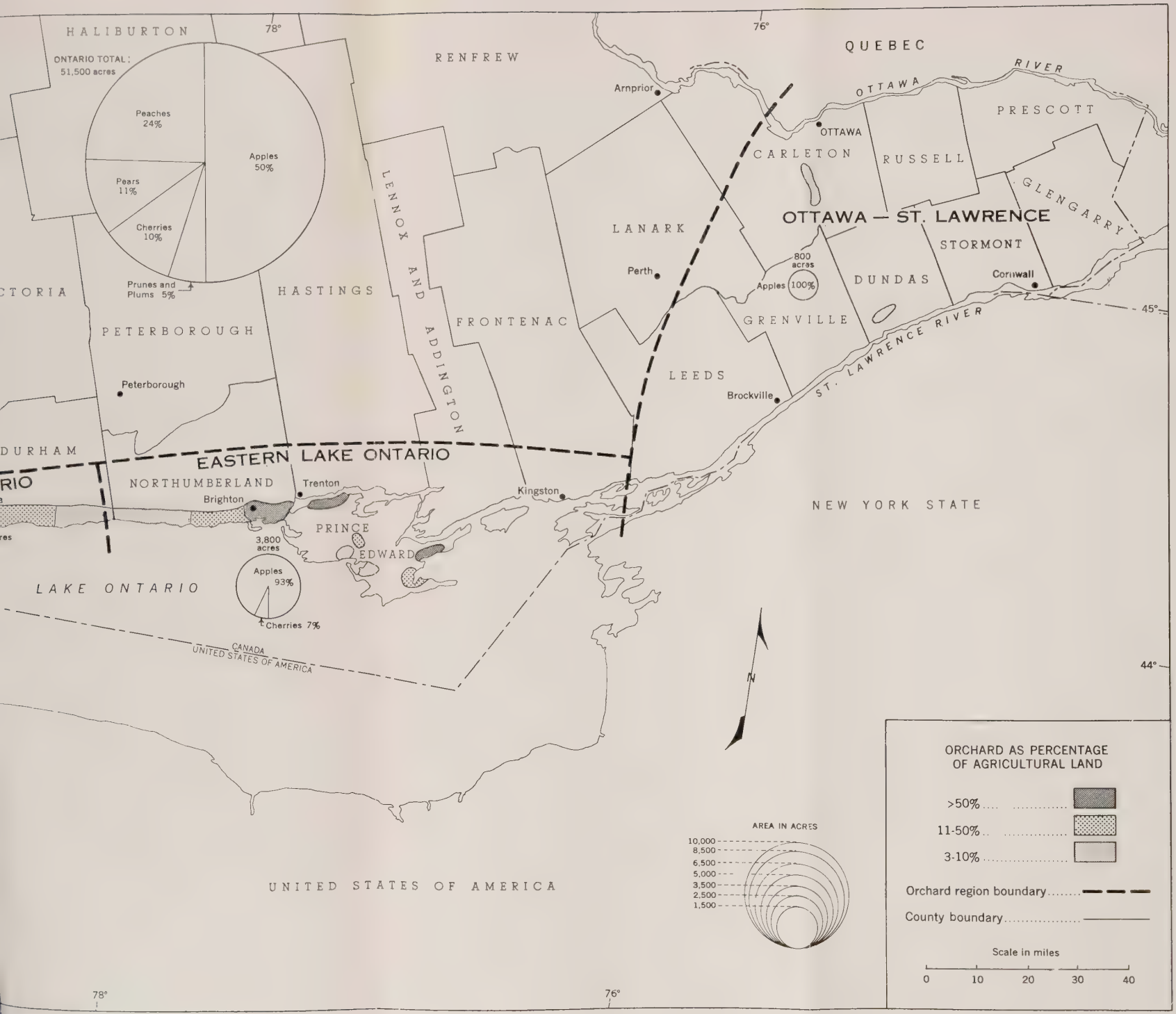
VALUE OF PRODUCTION, 1960
($'000)

Tree Fruit	B.C.	Ont.	Que.	N.B.	N.S.	Canada
Apples	9,523	7,017	4,288	480	1,839	23,147
Peaches	1,143	4,994	0	0	0	6,137
Pears	1,545	1,750	0	0	49	3,344
Cherries	1,187	2,032	0	0	0	3,219
Plums and Prunes	439	518	0	0	13	970
Apricots	674	0	0	0	0	674
TOTAL	14,511	16,311	4,288	0	0	37,494

D.B.S. Statistics

FIGURE 1A. Orchard acreages and tree-crop percentage distribution for Canada and major orchard provinces. Acreage data from Census of Canada, 1961. All orchards with 25 trees or more included.

FIGURE 6. The orcha



egions of Ontario.

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In this issue:

Area-differential productivity of agricultural resources and off-farm migration on the Canadian prairies *M. L. Szabo*

Notes on land use and landscape evaluation in a fringe area of the Canadian Shield *J. W. Maxwell*

Three-dimensional vector technique for analyzing till fabrics: discussion and FORTRAN program *J. T. Andrews and K. Shimizu*

The mixing of the waters of the Liard and Great Bear rivers with those of the Mackenzie *J. Ross Mackay*

Pattern of coastal uplift and deglacierization, West Baffin Island, N.W.T. *J. T. Andrews*

Preservation of vegetation and patterned ground under a thin ice body in northern Baffin Island, N.W.T. *G. Falconer*

National Advisory Committee on Geographical Research: Report on the first year of operation

Comité consultatif national de la recherche géographique Rapport de la première année d'activité